THE LONGITUDE AND LATITUDE Found by the INCLINATORY OR *Dipping Needle*;

Wherein the
Laws of Magnetism are also discover'd.

To which is prefix'd,
An *Historical Preface*; and to which is subjoin'd,
Mr. ROBERT NORMAN's *New Attractive*, or
Account of the first *Invention* of the *Dipping Needle*.

By WILL. WHISTON, M. A.
Sometime Professor of the Mathematicks in the
University of CAMBRIDGE.

Καὶ πᾶσαι πτολίων τείχοι, καὶ πρήονες ὄχθαι,
Οὔρεα δ' ὑλήεντα, καὶ ἄγρια κύματα πόντου
Ἔυβατα δὴ, καὶ εὔπλοα ἔσονται ἤμασι κείνοις.
Orac. Sibyll. III. v. 715, 716, 717.

LONDON:
Printed for J. SENEX, at the *Globe* in *Salisbury-Court*;
and W. TAYLOR, at the *Ship* in *Pater-Noster-Row*.
MDCCXXI.

THE

LONGITUDE

AND

LATITUDE

FOUND BY THE

INCLINATORY

OR

Dipping Needle.

TO

The Right Honourable THOMAS *Earl of* Pembroke *and* Montgomery.

The Right Honourable JAMES *Earl of* Berkley, *First Commissioner of the Admiralty.*

The Right Honourable THOMAS *Earl of* Westmorland, *First Commissioner of Trade.*

The Right Reverend Father in God PHILIP *Lord Bishop of* Hereford.

The Right Honourable THOMAS *Lord* TREVOR.

Sir GEORGE BYNG, *Kt. Admiral of the* Red, *and First Commissioner of the Navy.*

Sir JOHN JENNINGS, *Admiral of the* White.

Sir JOHN NORRIS, *Admiral of the* Blue.

Sir WILL. SANDERSON, *Master of* Trinity-House.

Sir THOMAS HANMER, *Bart.*

Sir

Sir ISAAC NEWTON, *President of the Royal Society.*

SPENCER COMPTON, *Esq*; *Speaker to the Honourable House of Commons.*

WILLIAM LOWNDS, *Esq*;

Dr. EDMUND HALLEY, *Astronomer Royal, and Savilian Professor of Geometry.*

Dr. JOHN KEILL, *Savilian Professor of* [redacted]

Mr. NICHOLAS SANDERSON, *Lucasian Professor of the Mathematicks.*

Mr. THOMAS SMITH, *Plumian Professor of Astronomy.*

Commissioners appointed by Act of Parliament for the Discovery of the LONGITUDE.

This METHOD for that Discovery is, with all due Submission, humbly Dedicated by

The AUTHOR.

AN Historical PREFACE:

Giving some ACCOUNT of the Invention of Magnetick Needles; especially of the Inclinatory or Dipping Needle; and the gradual Improvements therein made, till the Discovery of the Longitude thereby.

HOW *long it is since the* Magnet *or* Loadstone *has been taken notice of, and distinguish'd from other Mineral Stones, is not now known. 'Tis mention'd frequently, since the Time of* Plato; *and several little Attempts have been anciently made to solve its Appearances. But then all this came to no more than the Knowledge of the Magnet's* Attractive *Power, with relation to other Magnets, or to Iron: while its* Directive *Power, disposing its Poles nearly*

along the Meridian of every Place; and occasioning all Needles, Wires, or long Pieces of Iron touch'd by it, to point nearly North *and* South, *which is by much its principal Property, was entirely unknown. Nor does it appear that before the latter Part of the Thirteenth Century, one Syllable occurs in the old Books relating to that matter. About* A. D. 1260, *as some say,* Paulus Venetus *brought in the* Mariners Compass, *and applied it to the Uses of Navigation; altho' not as an Invention of his own, but as deriv'd from the* Chinese; *who are pretended to have had it still more anciently. Yet has the very Learned* Renaudot *given such Reasons against this Antiquity of the* Mariner's Compass *in the Oriental Parts, both as to* Arabia *and* China, *that 'tis much more probable they knew nothing of this* Compass, *till the* Europeans *brought it to them. Others therefore, with much greater Probability, ascribe this noble Invention, which is one of the the greatest for the Uses of Mankind that ever was yet made, to a* Neapolitan, John Goia *by Name,* A. D. 1300, *who is, however, owned to be the First that apply'd it to the Guidance of Ships in the* Mediterranean. *Nor is that unlikely, which Dr.* Wallis *conjecturas; That this* Nautical Compass *came to its Perfe-*

Dissert. of the Chinese Sciences, &c. p. 287. —294, & 389.

tion by Steps, and by several partial Discoveries and Improvements, before any one was able to apply it to the business of Navigation. Take his Notion in his own Words: "Where Inventions "creep in by degrees, says the Dr. it "must not be thought strange if it be not "easy to say who is the first Inventor. "In the present Case, he who first Obsery'd "(I know not by what accident) that "the Magnet hath a Polarity, or Incli- "nation Northward, made the First Step "towards this Invention. This, I think, "was at First wont to be shewed by "putting a Magnet into a little Boat, "Swimming on Water, when it was "obsery'd that the Magnet would of "it self so Steer this little Boat, as that "a certain Point in the Magnet would, if "not hindred, turn towards the North: "which Point was thereupon called the "Magnet's North Pole. He that after- "wards obsery'd that this Verticity or "Polarity was communicable to a piece of "Iron or Steel, rubbed on a Magnet, "added a further Step towards the busines "in Hand. And he who contrived a "Way to set a Needle or Piece of Steel, "(so touched,) on a sharp Pin, so as "(in the Air) to move Horizontally "thereon, so as (of it self) to find out "the North and Point towards it, as

Philos. Transact. N°. 278.

" (before) the swimming Magnet (in its
" Boat) had done on the Water, had now
" discovered a New Experiment in Na-
" tural Philosophy, very surprizing. But
" this cannot yet be called Circulus Nau-
" ticus, (or the Mariners Compass,)
" till they had further contrived a Way
" how to put a Needle, (thus pois'd,)
" into a Box, with a Compass or Circle
" round it, so divided as to denote the
" Azimuthal Points of the Horizon: (or,
" as they be now called, the Points of the
" Compass;) and so commodiously to
" fix this Box, (so prepared,) to the Ship,
" as thereby to instruct the Mariner (or
" Steers-man) towards what Point of the
" Compass the Ship moved; that (by the
" help of the Rudder) he might put it
" into such a Course, as was proper for
" his Voyage. And it was now indeed
" Pyxis Nautica, or Circulus Nauticus,
" (the Mariners Box, or Compass) but
" not till then. And he who First con-
" triv'd this Application did Compleat
" the Invention of Circulus Nauticus.
" But all those antecedent Discoveries
" were Steps towards it, and Parts of the
" Invention. Thus far Dr. Wallis. Who
also there endeavours to claim this Inventi-
on to the English Nation, from the English
Names Compass; and Box or Boxel;
which are imitated by most other Nations
used

used to Navigation. However, thus far is certain, that this Noble Invention was made and applied to Navagation a little before our Countryman John Wiclif appeared in the World, and so before the First direct Origin of the Protestant Reformation in Europe. But still it appears all along the 14th and 15th Centuries, that there was no Apprehension that such a Magnetical Horizontal Needle pointed any where, to any other than the North and South Points of the Horizon: And when any Declination therefrom appear'd, it was supposed to be from some Error or Defect in the placing of the Wires, or the ill Make of the particular Compass; and not to the real Variation of such a Needle, when good, and well hung, from that Direction. Sebastian Cabot, a Venetian, is generally allow'd to have been the first who discovered that Variation to be real, and the same in the same Place in all the Needles. And this was A. D. 1500. just before Luther arose in Germany; and occasion'd that great Event of an actual Protestant Reformation, both there and elsewhere. Yet was it still thought, even by Mr. Norman and Mr. Burrows themselves, the first exact Observers of the Inclination and Variation, that the Declination from the Meridian was only different in different Places and Countries:

Norman's *New Attract.* c. 9. Burrows's *Variation*, c. 10.

While

While it was, after all, ſuppoſed to be one and the ſame during all Ages, in the ſame Place or Country, notwithſtanding. It being then commonly ſuppoſed owing to certain Magnetick Continents, or Mountains, or the like Originals; which continuing the ſame for all Generations, might naturally occaſion ſuch a Declination: different indeed in ſeveral Countries, but in the ſame Country invariably the ſame. But ſtill, to uſe Dr. Wallis's Words here, inſtead of my own, "I think it is now "agreed on all hands, that (what we "call) the Variation of the Variation, is "an Engliſh *Diſcovery, (of Mr.* Gellibrand, "*if I miſtake not; one of Sir* Thomas "Greſham's *Profeſſors, at* Greſham Col-"*lege,) about the Year* 1625. *Who alſo, as the Doctor there informs us, "cauſed a great Concave Dial to be erected "in the* Privy-Garden *at* Whitehall, "*[which is ſtill remaining, as to the "main Body of it] with great Care to "fix a true Meridian Line, and with a "large Magnetick Needle, ſhewing its "Variation from that Meridian from "time to time". And where, give me leave to add, Mr.* Bond *informs us, that Variation was taken* A. D. 1665. *and found to be,* June 8. 1°. 22'. 30". Weſt. *And there again, I do not doubt, it was taken, as he informs us, in* June, A. D. 1666.

Philoſ. Tranſact. N°. 276, *and* 278.

Long. Found. p. 13, 14.

1666. and found to be 1°. 35'. 36". and that by some of the best Observers of that Age: Tho', alas! the Remains of that Noble Concave stand now wild and batter'd; with the Brass generally gone; and no Tidings of that large Magnetick Needle, no less than Three Feet in Diameter, as the Diameter of the Concave it self, still remaining, implies; or of the Nicety of those Divisions, or of the Exactness of those Contrivances, whereby, even in an Horizontal Situation, the Angle was taken nearer than to a single Minute, and this in Agreement to Analogy in the foregoing and succeeding Observations of others also. A Loss the more to be lamented, because this Degree of Nicety has been since so far forgot, that the Learned will hardly believe it ever had been, or ever can be brought to that Degree of Perfection, which this Concave, and the Observations formerly there made, do suppose. I hope some of our curious Virtuoso's about the Court will take care to have this noble Monument of the Care and Accuracy of the last Age for Magnetick Experiments of this Kind recovered, and put to its original Use: that we may be able there to shew this, and the following Ages, not only the Variation of the Horizontal Needle, as before; but also the Inclination of the Dipping Needle

to the same Degree of Accuracy, which the last Age here shew'd the Variation. But to leave this Digression, and to proceed.

Some time after this, about A. D. 1663, Mr. Bond, already mentioned, embraced the Hypothesis of Moveable Magnetick Poles, and suppos'd them in, or above, our Air; and from that Motion of theirs, which he estimated to be Westward, and to make its Revolution in 600 Years, he computed a Table of the Variation for London, from 1663 to 1715, extant in the Philosoph. Transactions. Which, tho' it agreed well enough with the Observations till the Beginning of this Century, has since too far disagreed from them; and so has discovered some Error or Defect in that Hypothesis on which it was founded.

Longitude found, p. 2. —9.

Philos. Transact. N°. 40.

However, this Notion in general of Moveable Magnetick Poles, has always seemed so probable, or rather necessary, ever since the Variation has been it self found to Vary, and this after a certain regular manner also; that Mr. Philips, before Mr. Bond, asserted the same; and stated the Revolution to be in 370 Years. And after all, our Learned Dr. Halley, who has far outdone every body upon this Subject, has determined it to be so. Only he has thought himself obliged to add the Hypothesis of two other fixed Poles: and from the joint Effects of all Four Poles,

Apud Bond. Longitude found, p. 7, &c. Philos. Transact. N8. 148.

Poles, and from thoſe only has he been able to bring this Variation of the Variation *to ſome kind of Syſtem, agreeable to the Obſervations. He has alſo been obliged to lengthen the Period of the moveable Poles Revolution: and, as Mr.* Bond *had enlarged Mr.* Philips's *Number, from 370 Years to 600: So has Dr.* Halley *enlarg'd the ſame farther from 600 to 700 Years. Take the Subſtance of Dr.* Halley's *Notion, which was the Reſult of many and accurate Obſervations, in his own Words, as they ſtand in the* Philoſophical Tranſactions, *N°. 148.*

"*Theſe Obſervations, ſays the Doctor,* "*plainly demonſtrate the Impoſſibility of* "*reconciling theſe* Variations *by the Theo-* "*ry of* Bond: *which is by* Two Magne- "tical Poles, and an Axis, inclined to "the Axis of the Earth. *From whence* "*it would follow, that under the ſame* "Meridian *the* Variation *ſhould be in all* "*Places the ſame way.* ——*They may* "*ſerve as a ſure Foundation for this* "Theory, That the whole Globe of the "Earth is one great *Magnet*; having "Four *Magnetical Poles*, or Points of "Attraction: Near each *Pole* of the "*Equator* Two; *and that* in thoſe Parts "of the World which lie near adjacent "to any one of thoſe *Magnetical Poles*, "the *Needle* is governed thereby: the

" neareſt *Pole* being always predominant
" over the more remote. *The Parts of*
" *the Earth, wherein theſe* Magnetical
" Poles *lie, cannot as yet be exactly de-*
" *termined, for want of ſufficient* Data *to*
" *proceed* geometrically. *But, as near*
" *as Conjecture can reach, I reckon that*
" *the* Pole, *which is at preſent neareſt to*
" *us, lies in, or near the* Meridian *of the*
" Land's End *of* England, *and not above*
" 7 Degrees *from the* Pole Arctick. *By*
" *this* Pole *the* Variations *in all* Europe,
" *and* Tartary, *and the* North Sea, *are*
" *principally governed; tho' with regard*
" *to the other* Northern Pole, *whoſe Si-*
" *tuation is in a* Meridian *paſſing about*
" *the Middle of* California, *and about*
" 15 *gr. from the* North Pole *of the*
" *World. To this the* Needle *has chiefly*
" *reſpect in all the* North America, *and*
" *in the* Two Oceans *on either ſide there-*
" *of, from the* Azores, *Weſtwards, to*
" Japan, *and farther. The* two Southern
" Poles *are rather farther diſtant from*
" *the* South Pole *of the World; the one*
" *about* 16 *deg, therefrom is in a* Merid.
" *ſome* 20 *deg. to the Weſtward of* Ma-
" gellan's Streights, *or* 95 *deg.* Weſt
" *from* London. *This commands the*
" Needle *in all the* South America, *in*
" *the* Pacifick Sea, *and the greateſt Part*
" *of the* Æthiopick Ocean. *The Fourth*

" *and laſt* Pole *ſeems to have the greateſt*
" *Power, and largeſt Dominions of all;*
" *as it is the moſt remote from the* Pole
" *of the* World, *being little leſs than* 20
" *deg. diſtant therefrom: In the* Meridian
" *which paſſes through* Hollandia Nova,
" *and the Iſland* Celebes, *about* 120 *deg.*
" East *from* London. *This* Pole *is pre-*
" *dominant in the* South *Part of* Africa,
" *in* Arabia, *and the* Red Sea, *in* Perſia,
" India, *and its Iſlands; and all over the*
" Indian Sea, *from the Cape of* Good
" Hope, *Eaſtwards, to the Middle of the*
" *Great* South Sea, *that divides* Aſia
" *from* America. *This ſeems to be the*
" *preſent Diſpoſition of the* Magnetical
" Virtue *throughout the whole Globe of*
" *the Earth.* ——*Now conſidering the*
" *Structure of our Terraqueous Globe,*
" *the only way to render this Motion in-*
" *telligible and poſſible, is to ſuppoſe it*
" *poſſible to* turn about the Center of the
" Globe, having its Center of Gravity
" fix'd and immoveable in the ſame com-
" mon Center of the Earth. *And there*
" *is yet requir'd, that this moving* Inter-
" nal *Subſtance be* looſe, *and detach'd*
" *from the* External *Parts of the Earth*
" *whereon we live. So then the* Exter-
" nal *Parts of the Globe may well be*
" *reckoned as the Shell, and the* Internal *as*
" *the* Nucleus *or* Inner Globe, *included*

 " *with-*

" within ours, with a fluid Medium be-
" tween. Which, having the same com-
" mon Center, and Axis of Diurnal Ro-
" tation, may turn about with our Earth
" each 24 Hours. Only this Outer
" Sphere having its turbinating Motion
" some small Matter either swifter or
" slower than the Internal Ball; and a
" very minute Difference in length of
" Time, by many Repetitions, becoming
" sensible; the Internal Parts will by de-
" grees recede from the External, and,
" not keeping pace with one another, will
" appear gradually to move either East-
" wards or Westwards, by the Difference
" of their Motions. So that if this Ex-
" terior Shell of Earth be a Magnet,
" having its Poles at a distance from the
" Poles of Diurnal Rotation; and if the
" Internal Nucleus be likewise a Magnet,
" having its Poles in two other Places,
" distant also from the Axis, and these
" latter, by a gradual and slow Motion,
" change their Place in respect of the
" External; we may then give a reasona-
" ble Account of the Four Magnetical
" Poles; as likewise of the Changes of
" the Needle's Variations, which, till
" now, hath been unattempted. The
" Period of this Motion being wonderful
" great, and there being hardly an hun-
" dred Years since those Variations have

 " been

" been duly observ'd, it will be very hard " to bring this Hypothesis to a Calculus, " ——The Period of this Motion ap- " pears, by all Circumstances, to be of " many Centuries of Years. ——We may " with some reason conjecture, —that the " whole Period thereof is performed in " 700 Years, or thereabouts". Thus far Dr. Halley's own Account. To whose entire Discourse in that Transaction, and the excellent Map of those Variations publish'd afterwards, I must still refer the curious Reader.

Thus far concerning the gradual Improvements made in the Knowledge of the Magnetick Horizontal Needle's Variation, and the Consequences thence deducible. I now proceed to what I mainly intend in this Preface, I mean an Account of the Invention of the Inclinatory or Dipping-Needle; the Observations hitherto made with it; and the great Uses it may be apply'd to: Which are no less than the compleat Discovery of the Longitude and Latitude, both by Sea and Land.

Now the first Inventor of the Inclinatory or Dipping-Needle was, without all question, an Englishman, Robert Norman by Name, a Compass-maker at Wapping, in the Suburbs of London, on or about A. D. 1576. as is attested not only by his own Account in his New Attractive,

tive, *dedicated to Mr.* Burrows, *a very good Mathematician, and great Sailor at that Time; but at the same time was allow'd to be his Invention by Mr.* Burrows; *as well as by Dr.* Gilbert, *the Father of Magnetical Philosophy soon afterward, in these Words:* "*This is that*

Burrows of Variation, Pref.

Gilbert de Magnete, l. 1. c. 1.

"Robert Norman, *that skilful Seaman,* "*and ingenious Artificer, who first found* "*out the Inclination of the Magnetick* "*Needle*". *Mr.* Bond *also assures us, about a Century after this Invention,* "*That himself saw an Inclinatory Needle* "*of one Dr.* Merret's, *which was made* "*by this* Robert Norman, A. D. 1578. "*and which he fitted up for the Doctor's* "*Use*". *Take the History of this Original Invention in Mr.* Norman's *own Words, which you will meet with in the* IIId Chapter *of that* New Attractive: *which is added at the End of these Papers.*

Long-found, p. 11.

Having, *says he*, made many and divers compasses, and using alwaies to finish and end them before I touched the needle, I found continually, that after I had touched the yrons with the Stone, that presently the north point thereof would bend or *Decline*, downwards under the Horizon in some quantitie: insomuch that to the Flie of the Compasse, which before was made equall, I was still constrained

to

to put ſome ſmall peece of waxe in the South part thereof, to counterpoiſe this *Declining*, and to make it equall againe.

Which effect hauing many times paſſed my hands without any great regard thereunto, as ignorant of any ſuch propertie in the Stone, and not before having heard nor read of any ſuch matter: It chaunced at length that there came to my hands an Inſtrument to bee made, with a Needle of ſixe inches long, which needle after I had polliſhed, cut off at juſt length, and made it to ſtand levell upon the pinne, ſo that nothing reſted but only the touching of it with the Stone: when I had touched the ſame, preſently the North parte thereof *Declined* downe, in ſuch ſort, that being conſtrayned to cut away ſome of that part, to make it equal again, in the end I cut it too ſhort, and ſo ſpoiled the needle wherein I had taken ſo much paynes.

Hereby beeing ſtroken into ſome choller, I applyed my ſelf to ſeeke further into this effect, and making certayne learned and expert men (my friends) acquainted in this matter, they adviſed me to frame ſome Inſtrument, to make ſome exact tryall, how much the Needle touched with the Stone would *Decline*, or what greateſt Angle it would make with the Plaine of the Horizon. *Thus far Mr.* Norman. *But*

But what is here chiefly remarkable as to us, is the exact Quantity of the Inclination of this Needle at London then, A.D. 1576. noted here by Mr. Norman, about 71°. 50′. as also the like exact Quantity of the Variation there about the same time, noted by himself, and by his Friend and Patron Mr. Burrows, 11°. 15′. Eastward. Which Observations of those two Angles are, for certain, the oldest and best now extant in the World: And which I take to be Original Standards for the Inclination and Variation of Magnetick Needles, with their several Variations, in all future Ages; as the Lunar Eclipses, noted at Babylon by the ancient Chaldeans, are Original Standards for the Periods and Motions of the Sun and Moon, with their several Inequalities, for all future Ages. Nor will these Observations of the Inclination and Variation be perhaps hereafter of less Use in Navigation, than the other have ever been in Astronomy.

Norman's *New Attract.* c. 4, 7, 9. Burrows's *Variation*, c. 3, 7, 9.

Nor may we pass over another Notion advanc'd by Mr. Burrows at that time; viz. That the Magnetick Poles of the Earth were different from the Poles of the Equator: Whose Distance he also endeavoured to find; with good Skill as to the Mathematick Part, but with ill Success in the Practice. His Data being too uncer-

Variation, c. 8.

tain,

tain; and the Poles mutable; neither of which he was then acquainted with. However, had the succeeding Ages but adher'd to Mr. Burrows's Opinion, that the Poles of the Terrestrial Magnet were different from the Poles of the Earth, and by consequence their Equator and Parallels different from the Earth's Equator and Parallels, they had hardly so generally confin'd their Thoughts to the discovery of the Latitude by the Inclinatory Needle, as the contrary Mistake oblig'd them to do: But might probably have thought of discovering the Longitude thereby also. Tho' indeed the weak and precarious Methods made use of by Dr. Gilbert, Dr. Ridley, Mr. Bond, and many others, after the Days of Mr. Norman and Mr. Burrows, for that Discovery of even the Latitude by this Needle; a thing so easy in it self, had they gone by Observations and Facts, instead of Notions and Hypotheses; give one but a small Opinion of their Capacities for the Discovery of the Longitude thereby. Which, tho' in its own Nature very fit for such a Purpose, yet requiring more and nicer Observations than the other, 'tis no great Wonder the Discovery of the Longitude escaped their Notice at that Time. Cabeus indeed at Ferrara, did wish he could try the Angle of Dip on a Terrella or Spherical Loadstone;

Gilbert, l. 5. c. 6.
Ridley's *magnetick Motions.* l. 20. c. 36, 37, 38.
Bond's *Caroline Tables.*
Cabeus, *de Magnet.* l. 22.

stone; but wanted one sufficient for his Purpose. He also endeavour'd to procure actual Observations of that Dip at Sea, in a Southern Voyage; but the Person employed dying before his return, he got but a very imperfect Account thereof. About A. D. 1608, Mr. Hudson, a famous Sailor, and Discoverer of unknown Countries, from whom Hudson's Bay takes its Name, sailed towards the Pole, beyond the North Cape: and took with him a good Inclinatory Needle; with which he made several highly valuable Observations of the Angle of Inclination, from the Latitude of 61°. 11'. to that of 75°. 22', or from 79 of such Inclination then, to 89½. and so almost to the then Northern Magnetick Pole it self. Which Observations we meet with in Vol. III. of Purchas's Pilgrim, or Collection of such Voyages; and which are of the greatest Consequence to my present Design. About the same Time Mr. Henry Philips, in his Seaman's Calendar, as is already mentioned, approved of moveable Magnetick Poles; and computed their Period to be in 370 Years.

After him, tho' not very long, Mr. Henry Bond, Sen. a Teacher of Navigation in Ratcliff, near London, began to entertain Thoughts of Magnetick moveable Poles, placed above the Earth,

and

and revolving in 600 *Years, of which before. He also, after* Nautonier *and* Linton, *whose Books I have not seen, entertained Thoughts of discovering the Longitude by the Knowledge of their Position and Motion, and by the Consequent Angles of Inclination of the Dipping Needle, in the several Parts of the World. He first wrote, as himself tells us, in his* Seaman's Kalendar, *published about* A. D. 1645. "That, *without* "*Doubt, the Longitude would be found* "*by the Observation of something below the Moon.*" *He afterwards,* A. D. 1676. *published a distinct Treatise in* 4*to*, *intituled,* The Longitude found: *which has* King Charles II. *Royal Privilege before it: and which, as the Book it self informs us, was examined by Six of the most competent Judges about the Court at that Time. Who then seemed to hope that Mr.* Bond *had some great Secret, and would discover the Longitude. However, Mr.* Bond *gives us not in that Book, any particular Account of the Facts he went upon, as to the Inclination of the Dipping Needle: there being, that I remember, but two such Observations set down in all his Book: the one in the* East, *and the other in the* West-Indies: *Together with the Inclination at* London, *to be collected from the pointing of that*

Ridley *præf.* Hook: *op. posthuma, p.* 482, 483.

Long-found, p. 3.

p. 17, 18, 19. *&c.*

Needle in his Scheme thereof. Nor does he give us any particular Rules or Examples of the Manner how he would discover the Longitude by that Needle. Nay, when, on the Reverse, he attempted to find that Inclination from the Longitude given, he built upon such precarious and inconsistent Hypotheses, as real Facts; and withal made such Mistakes in his Trigonometrical Calculations; (which were soon demonstrated to be such by Mr. Blackborough, in his Longitude not found;) that 'tis a Wonder the Publick took so much Notice of it. Tho' it was indeed great Pity, that when so noble a Thought was started for the Discovery of the Longitude, and so fair an Occasion given, for considering the entire magnetick Power, the truly Learned did not better examine into that Matter, and cause more authentick Observations of the Inclination of the Dipping Needle to be made for that Purpose: but left all to stand or fall by Mr. Bond's own Hypothesis and Calculations. The Consequence of this great Disappointment seems to have been, at least with us, an almost intire Disuse of Dipping Needles ever since: as will appear in the following History.

Colonel Windham, a very curious and inquisitive Gentleman, indeed, did both in, and ever since the Days of Mr. Bond,

Bond, cultivate this magnetick Part of Philoſophy; and particularly made conſiderable Uſe of the Dipping Needle, both by Sea and Land: from whoſe Obſervations made about A. D. 1672. with the Allowance of the Increaſe ſince that Time, I have determined the Dip at Salisbury in my little Map prefixed to this Treatiſe: and from whoſe other Obſervations, made at Sea, and on the French Coaſt, I would willingly have determined the like Dip at thoſe Places alſo, could he have recovered the Papers wherein they were ſet down. But they being not yet found, I could not do it. That great Mathematician and Philoſopher alſo Monſ. Fatio, juſt now aſſures me, that the Honourable Mr. Boyle had a Terrella, and a little Inclinatory Needle; both which he lent him, above Thirty Years ago. That he tried a great Number of Experiments with them, and that they were conſonant to what I have tried ſince my ſelf. He alſo intimates, that He was ſenſible that ſome Uſe might be made of this Dipping Needle, in order to diſcover the Longitude; tho' he freely acknowledges, that "My Theory of the "Properties of Magnetiſm, beſide the "actual Obſervations, has a Degree of "Ripeneſs and Simplicity, which he "knew nothing of.

A. D.

A. D. 1700, Dr. Halley *went to Sea, on purpose to compleat his Observations of the Variation, with an Horizontal Needle only. Whereas if he had taken a large and good Dipping-Needle with him also at the same time, and had observ'd, with equal Exactness, the* Inclination, *as the* Variation, *it was next to impossible he should have missed of discovering the Longitude thereby; as will appear in the Sequel. The very same Year did our great Astronomer of* Wanstead, *the Reverend Mr.* Pound, *in Company with Mr.* James Cunnlogham, *take a Voyage to* China; *and most part of the way they made Observations of the Inclination by a Dipping-Needle which they had with them: Which Observations have been published, from Mr.* Cunningham's *Journal, in the* Philosophical Transactions. *But, by what hard Fate I know not, their Dipping-Needle prov'd so bad, and the Observations so disagreeable the one to the other, and most of them so different from the Analogy of all other such Observations, in or near the same Seas, that, excepting the gross general Correspondence, of affording an Horizontal Situation somewhat beyond the Equator; the Increase of that Dip Southwards; and the Return to the Horizontal Situation near the* Western *Coast of* China, *in which all Needles con-*

N°. 292.

spire,

ſpire, no particular Degrees of Inclination can be at all depended on in this whole Collection.

A. D. 1706, Pere Noel, *of the Society of* Jeſus, *when he ſailed from* Lisbon *to the* Eaſt Indies, *as a Miſſionary, had along with him a good Inclinatory Needle; and all the way made accurate Obſervations of the Angle of Inclination, as far as* Fort St. George: *Which, with many other curious Obſervations, and an Hypotheſis of his own with reſpect to Two large Magnets he ſuppoſed to be within the Earth, he publiſhed at* Prague *in* Bohemia *ſome time afterward. And indeed, I eſteem this to be the principal Set of Inclinatory Obſervations that I have yet ſeen; eſpecially as they appear to have been carefully made, and with a good Inſtrument, and to contain the true Dip over ſo large a Part of the World.*

A little after this, about A. D. 1708, *Monſieur* Feuillee, *a very curious and obſerving Perſon, when he was got beyond* South America, *to* Lima *in* Peru, *procur'd himſelf a good Dipping-Needle there: and therewith obſerv'd the Inclination, with great Care and Exactneſs, from* 13°. *to* 36°. *of* South *Latitude; or from* 18°. *of Dip to* 55°.

The Knowledge of theſe laſt Obſervations, I owe to that curious and diligent Natu-

raliſt

ralist and Mathematician, Samuel Molineux, Esq; who had them collected out of Monsieur Feuillee's Account of that Voyage: Who also the first of all thereupon intimated his Hopes to me, that by such Observations of the Variation and Dip compar'd together, the Longitude would, one time or other, be someway discovered; tho' at that time I had not the least Thoughts of any such thing.

Hitherto therefore, or till about the latter End of the Year 1718, I had no Notions of discovering the Longitude by the Way now propos'd. Nor was it possible I should have, since I did not then distinctly know what a Dipping-Needle was: nor indeed do I remember that, before That Time, I had ever seen such an Instrument in my Life. But the Occasion which turned my Thoughts this way, was as follows: About the Middle of November, A. D. 1718, came to me one Mr. Eberhard, a German, born at Isleben in Saxony, the very Town where Luther was himself born; who pretended to have a Method for discovering the Longitude by the Dipping-Needle; which he had been several Months proposing to the other Mathematicians and Virtuoso's in Town; tho' without being able to satisfy any of them, that he had made any such Discovery. Upon my Examination into his Method, which

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at first I thought might admit of some Mystery, which he conceal'd; I found at last, when he sent me Pere Noel's Book, it was little more than that Author's Hypothesis, already mentioned, of Two Internal Loadstones, and the Imitation thereof by the Insertion of small Loadstones under Maps, and within Terrestrial Globes: With some hopes he had, that Nature would afford a sort of Magnetick Needle, which should point East and West, as the ordinary ones pointed North and South. While yet he confessed he did not know that there was such a Power in Nature, as most certainly there is not; And yet without such a Power, all his Expectations must come to nothing.

Being thus disappointed in Mr. Eberhard's Proposal of discovering the Longitude, I could not, however, forbear to think of this, to me, wholly new Instrument, the Dipping-Needle it self: Nor did I know but it might possibly be applied to this Purpose, if well understood. Whereupon I had a strong Inclination to see a real Dipping-Needle, and to try some Experiments therewith: For those that Mr. Eberhard had shewed me were so very small, that they were entirely unfit for Philosophical Experiments. Nor did I well understand, by what I saw there, even the common Nature or Use of such

an Instrument. Accordingly, to satisfy my Curiosity, I soon enquired for such an Instrument, and found that Colonel Windham had one, tho' it was small, which upon my Application he readily lent me; and as readily shew'd me the way of using it: He inform'd me also what Observations he had made by a larger Instrument of that Kind; how the Dip stood when he was young; and how much it had increas'd in his Time: For which, and other the like Kindnesses ever since, I and the Publick are greatly obliged to him. For as soon as I had got this Dipping-Needle, I began to try some Experiments with it: Which tho' they immediately shewed that Mr. Eberhard's Hopes were ill grounded, yet seemed to promise somewhat considerable this way, could a practicable Method of Application be hit upon.

Now as I was musing of this Matter, and when I could think of no other way, Dr. Halley's Map of the Variation, already mentioned, came very seasonably to my mind: And I considered, that by such an inartificial way of describing the Curve Lines of equal Variation, how irregular soever, upon a Map, he had already given some Help for the Discovery of the Longitude, at least near the Cape of Good Hope: tho' the Quickness of the Mutation of those Lines, and their different

Posi-

Poſition in the reſt of the World, rendred that Method of ſhort Uſe there, and almoſt wholly uſeleſs elſewhere. When therefore I conſidered, that the Lines of equal Dip could hardly be more irregular than thoſe of the Variation; and well knew that their Mutation was a great deal ſlower; and that theſe might probably be uſeful over all the World; I conceived great hopes, that this way of Application of the Power before us might very probably diſcover the Longitude. And from this Time, and not before, do I properly date this my Diſcovery. But then, in what manner I immediately laid the Propoſal before the Commiſſioners appointed by Parliament for the Longitude; what diligent, but uſually fruitleſs, Searches I made both here, and in France, *for more good Inclinatory Obſervations; what Charges I have been at, and Difficulties I have met with, in the Mechanical Part of making and uſing this Inſtrument; what other Diſcouragements I met with; or what Aſſiſtances and Encouragements I have hitherto had; eſpecially from the Right Honourable the Lord* Paiſley, *and the free Uſe of his Loadſtones; and from Col.* Windham's *Informations, and former Experiments: What Magnetical Trials I have my ſelf firſt made, and afterward exhibited, before the beſt and moſt compe-*

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rent Judges; and this in order to bring both this Theory and Practice to Perfection; it may not, perhaps, be proper here minutely to relate any farther, I mean, than the following Papers, which contain the Success and Result of the whole, will inform the Reader. In the mean time, I hope the whole Sailing World will receive no little Benefit by these my Labours; and that the Publick will not, in any Nation, deny me those Rewards, which have been on purpose set apart for so useful a Discovery. I shall end this Historical Preface, in the Words which my dear Friend, Mr. Humphry Ditton, since deceas'd, and my self, used on a like Occasion formerly.

"I conclude all with my hearty Wishes, "as a Man, that this my Design may "tend to the common Benefit of Mankind: "as a Briton, that it may tend particularly to the Honour and Advantage of "this my Native Country: and as a "Christian, that it may tend to the Propagation of our Holy Religion, in its "Original Purity, throughout the "World.

London, Feb. 26. 17$\frac{1}{2}$.

Will. Whiston.

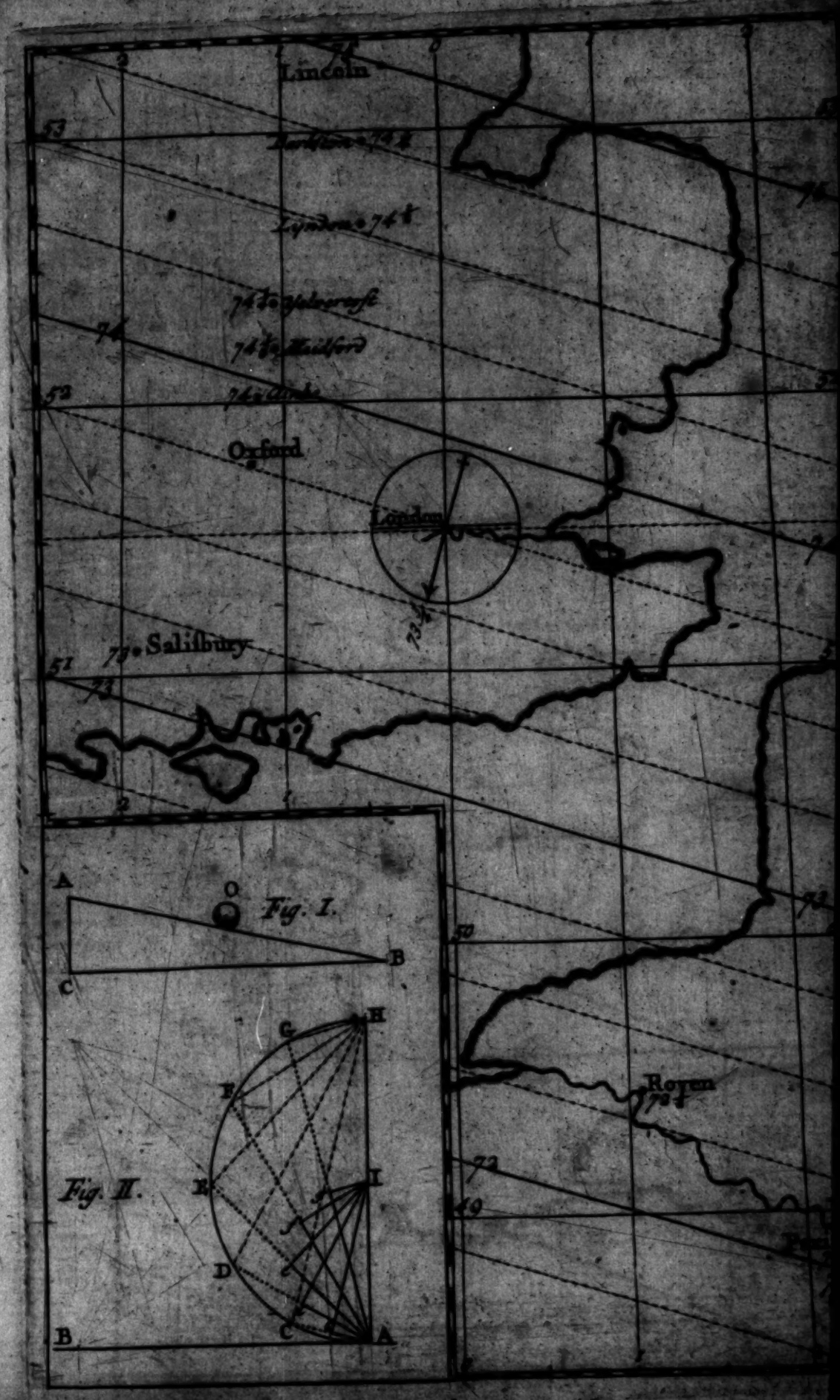
Lincoln
Oxford
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Fig. I.
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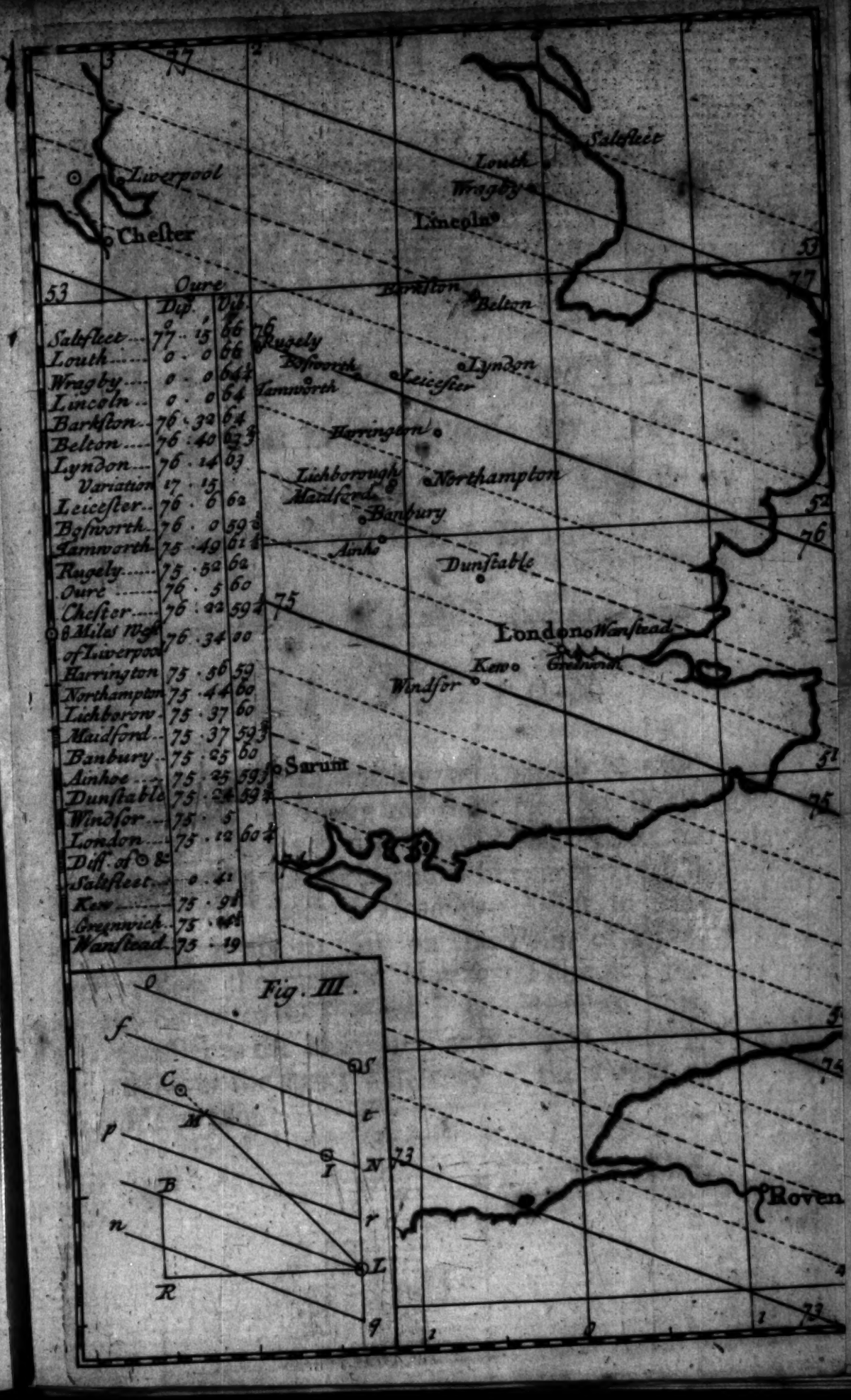
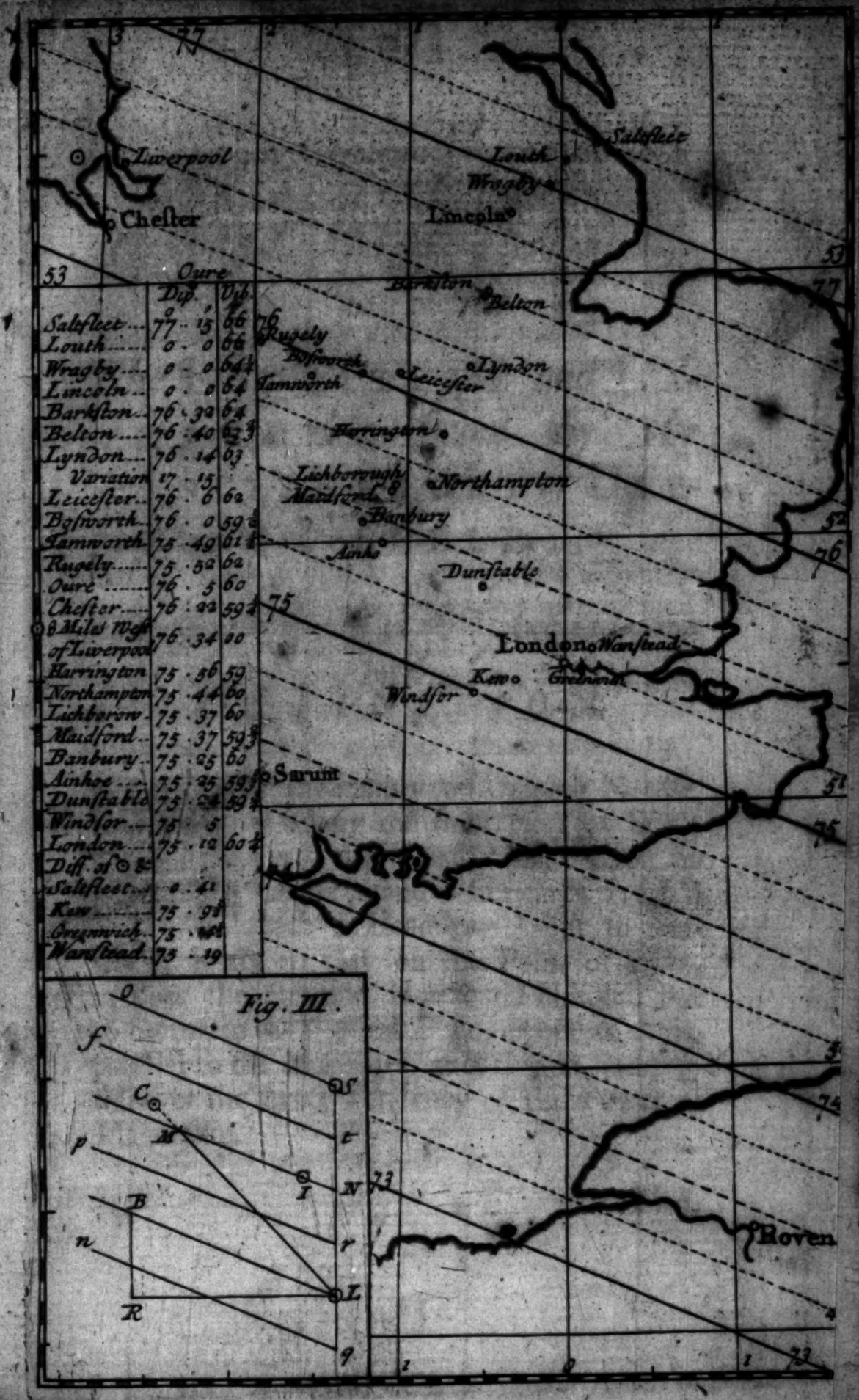
Fig. II.



	Dip.	Var.
	° ′	
Saltfleet	77 . 15	66 76
Louth	0 . 0	66
Wragby	0 . 0	64½
Lincoln	0 . 0	64
Barkston	76 . 32	64
Belton	76 . 40	63⅔
Lyndon	76 . 14	63
Variation	17 . 15	
Leicester	76 . 6	62
Bosworth	76 . 0	59⅔
Lamworth	75 . 49	61½
Rugely	75 . 52	62
Oure	76 . 5	60
Chester	76 . 22	59½
6 Miles W. of Liverpool	76 . 34	00
Harrington	75 . 56	59
Northampton	75 . 44	60
Lichborow	75 . 37	60
Maidford	75 . 37	59⅔
Banbury	75 . 25	60
Ainhoe	75 . 25	59⅔
Dunstable	75 . 24	59⅔
Windsor	75 . 5	
London	75 . 12	60½
Diff. of ☉ & Saltfleet	0 . 42	
Kew	75 . 9½	
Greenwich	75 . 16½	
Wanstead	75 . 19	



	Dip. °	′	Vis. ′
Saltfleet	77	15	66
Louth	0	0	66
Wragby	0	0	64½
Lincoln	0	0	64
Barkston	76	32	64
Belton	76	40	63
Lyndon	76	14	63
Variation	17	15	
Leicester	76	6	62
Bosworth	76	0	59½
Tamworth	75	49	61½
Rugely	75	52	62
Oure	76	5	60
Chester	76	22	59½
8 Miles Wsh of Liverpool	76	34	00
Harrington	75	56	59
Northampton	75	44	60
Lichborow	75	37	60
Maidford	75	37	59½
Banbury	75	25	60
Ainhoe	75	25	59½
Dunstable	75	24	59½
Windsor	75	5	
London	75	12	60½
Diff. of ⊙ &c			
Saltfleet	0	41	
Kew	75	91	
Greenwich	75	68	
Wanstead	75	19	

The LONGITUDE *and* LATITUDE *found by the* INCLINATORY *or* DIPPING NEEDLE.

DEFINITION.

AN Inclinatory or Dipping Needle, is a long and ſtrait piece of Steel, every way equally pois'd upon its Center, and afterwards touch'd with a Loadſtone; but ſo contriv'd, as not to play on the Point of a Pin, as does the common Horizontal Needle; but to Swing in a Vertical Plain, about an Axis parallel to the Horizon; and this in order to diſcover the exact Tendency of the Power of Magnetiſm.

N. B.

N. B. As to the Sort of Iron or Steel which is beſt for Magnetical Needles, Dr. *Ridley* gives us Direction in theſe Words, which I ſuppoſe are agreeable to Experience.

"Needles and Wires of Steel, "heated to an height, and redu-"ced back to a blewiſh Colour, will receive "a ſtronger Touch, and retain it ten times "longer, than Iron will, howſoever it be "hardened: yet Iron is beſt for Caps placed "near the Stone.

N. B. If you would have a ſtrong Touch, which ſhould not be laſting, it may be beſt ſometimes to touch the Needle with the Cap or Armature of the Loadſtone; but if you deſire a ſtrong and durable Touch, you muſt, by all means, touch it on the Stone it ſelf, and that as near as may be to the Poles thereof; the *North* End of the Needle on the *South* Pole, and the *South* End on the *North* Pole; and that a do-zen or twenty times together: Tho' as to this Repetition of the Touch, which is every where now ſo frequent, hear Dr. *Gilbert*, under the following Note.

N. B. Dr. *Gilbert*'s Direction for touching of Needles is this: "When you would touch a "Needle with the Loadſtone, you are to be-"gin at the Middle of the Needle, and draw "it to the End of it: And towards the End, "con-

" continue that Touch gently, or by a tender " Application, for some time; I mean for one " or two Minutes of an Hour: But do not re- " iterate the Motion from the Middle to the " End, (as the Custom is,) for thereby its " directive Power is perverted. *L. III. c.* 17.

OBSERVATIONS.

I. The true Tendency of the *North* or *South* End of every Magnetick Needle, is not at all towards that Place in the Horizon whither the Horizontal Needle points, but towards another directly under it, in the same Vertical; and in different Degrees under it, in different Ages and Countries. *Ex. Gr.* At *London* this Tendency is now of the *North* End of the common Needle, about 73° 45′ below the Horizon. Whereas *A. D.* 1576, when this Property was first discovered, it was about 71° 50′, as Mr. *Norman* assures us, in his *New Attractive*; which I have added at the End of this Paper.

This Observation is also manifest in all Tryals of common Magnetick Needles; which though exactly pois'd in an Horizontal Position, before they are touch'd with the Loadstone; do yet, after that Touch, tend towards this Direction: And when contriv'd so as to swing in that Vertical Plain, will never rest in any other Position,

Position, without some other Force to counterbalance that Tendency. And indeed, by this Alteration of the Equilibrium of Horizontal Needles, upon the Touch, it was, that Mr. *Norman*, at *Wapping*, first discovered and made the Dipping-Needle; in or about *A. D.* 1576, as himself informs us in his forementioned *New Attractive*: of which in the Preface.

II. This Line of the Needle's Tendency is therefore to be considered, when we treat of the Power of Magnetism, in the very same Manner as is the Line of Direction towards the Earth's Center, when we treat of the Power of Gravity. This Magnetick Power appearing to be equally constant and uniform in this Direction, as is the Power of Gravity in the other.

III. The Angle of Dip, or Inclination below the Horizon, is then only the true one, or the least of all; and the Angle of the Needle from the Nadir the greatest; when the Plain of the Needle's Oscillations is directly along the Magnetick Meridian, or when the Intersection of the Plain with the Horizon is the true Variation of the Needle in that Place.

IV. When that Plain is at right Angles with the former, or in the Magnetick *East* and *West*, this Angle of Dip or Inclination is a right Angle;

Angle; and the Needle does not at all aſcend from the Nadir.

Corollary. When therefore the Dipping Needle ſtands exactly perpendicular to the Horizon, the Interſection of that Plain with the Horizon, makes an Angle with the true *Eaſt* and *Weſt* Line, equal to the Variation of the Needle at that Place.

N. B. Becauſe, as we ſhall ſee hereafter, the Alteration of the Aſcent of the Needle is according to the Degrees on the Line of Sines; which at firſt differ very much, but at laſt exceeding little; this Angle of the Variation is diſcover'd beſt by the Dipping Needle, in this Poſition of its Plain, and not in that along the Magnetick Meridian.

N. B. If the Plain of the Needle therefore be but within Three, Four, or even Five Degrees of the Magnetick Meridian, the Angle of Inclination will be almoſt as exact as if it were perfectly along that Line. The Reaſon is obvious: For the Sine of 85° differing from that of 90° not quite the 250th Part of the Radius; this Difference can hardly ever come to more than one Third of a Degree, or 20′, and with us never comes to more than 4′. And the Sine of 87° ⅓ differing from that of 90°, not quite the 1000th Part of the Radius, or but one Quarter of the former Dif-

ference, this Error can hardly ever come to more than 5′, and with us never comes to more than 1′. Which Thing is of great Advantage for Practice, in finding the true Angle of Inclination with Dipping Needles: Though it has not indeed any Place in the finding the Angle equal to the Variation; which admits of no such Allowance for Inaccurrcy as is here mentioned.

V. Great Exactneſs is neceſſary in the Poiſe and Situation of the Dipping Needle; *viz.* that it be equally ballanced when either Edge is upward, that its Plain be exactly Vertical, or Perpendicular to the Horizon: And that the Beginning of the Diviſions be perpendicularly under the Axis of Motion; which, in ſmall Needles, are beſt provided for by a large circular Pedeſtal, with three Screws; and thoſe adjuſted by a Spirit Level, whoſe Plain is parallel to the Horizon. By which means, the Angles of Inclination will be equal, if either Side of the Inſtrument be turned *Eaſtward*; which otherwiſe will not happen.

N. B. Long Needles which will turn, in ſome degree, with the 120th or 130th Part of a Grain, and will ſtand in a perfect Equilibrium both horizontally and perpendicularly, will yet do ſo in no oblique Situation whatſoever. This is certain in fact; and plainly ariſes from a ſmall and uſually unperceiv'd Bending of the Needle, which makes the Center of Gravity a very ſmall matter different from the Center of Motion,

Motion, as Monſ. *Fatio* ſuggeſted to me. We muſt therefore correct this Inequality before we touch or uſe ſuch Needles: Which is eaſily done by a ſmall Poiſe of Braſs circular Wire, or any like ſmall Weight, placed on the lower Part of the Needle, and to be remov'd higher and lower, as Experience ſhall direct. For if you thus ballance this Power, the ſame Poiſe on a due Removal to its correſpondent Mark on the Needle, will ſerve for all other Inclinations. Thus my longer Needle of Four Feet was ballanc'd by a Poiſe of 1,77 Grains, and the other of Three Feet 11 ½ Inches by 2,44 Grains.

N. B. The Want of the diſtinct Knowledge of this Inequality, and of providing for its Poiſe, has rendred moſt of our Obſervations hitherto inaccurate, and the Angle of Inclination has been ſtated too ſmall. Accordingly the Dip at *London*, which by my former Needles of one Foot long, unpois'd, was only 73° ½, is in reality by theſe of four Foot pois'd, 75 ½. Nay, theſe laſt, when unpois'd, differ from themſelves when pois'd not leſs than 30 degrees; and make the Dip at *London* leſs than 45.

Corollary. Hence all Dipping Needles that pretend to Exactneſs, and that are to belong to the ſame Sea Chart, ought to be nicely adjuſted to the ſame Standard, both as to the Accuracy of their Poiſe, and Quantity of Dip at one certain Place; otherwiſe they will groſsly deceive the Obſervers.

LEMMATA:

Or Preparatory PROPOSITIONS; *Wherein the Laws of Magnetiſm are diſcovered.*

I. THE Loadſtone has both an *Attractive*, and a *Directive* Power united together: While Iron, touch'd by a Loadſtone, has the *Attractive*, but little or no *Directive* Power at all. I mean, that the Loadſtone not only *attracts* Needles, or Filings of Steel; but *directs* them to certain different Angles with reſpect to its own Surface and Axis. While Iron, touch'd therewith, does little or nothing more than *attract* them; and ſtill ſuffers them to lie along, or ſtand perpendicular to its Surface and Edges in all Places, without any ſuch ſpecial Direction.

This is a Matter of Experiment, and appears to be ſo upon Trial.

N. B. Neither the *ſtrongeſt*, nor the *largeſt* Loadſtones give a better Directive Touch to Needles, than thoſe of a more ordinary Virtue and Bigneſs; as I have found upon Trial: The Quickneſs of the uſual Vibrations not having been ſenſibly altered by ſuch Loadſtones. And Monſ. *Fatio* aſſures me, he has formerly experienc'd the ſame thing. Colonel *Windham* alſo has himſelf obſerv'd this, "That all Load-"ſtones have two Qualities, *viz.* an Attra-"ctive

" ctive and a Directing Quality; neither of " which depend on, or are an Argument of " the Strength of the other.

N. B. The *Attractive* Power of Loadſtones and of Iron, will greatly increaſe or diminiſh the Weight of Needles upon the Ballance; nay, will overcome that Weight, and ſupport other additional Weights alſo: while the *Directive* Power ſeems to have much ſmaller Effect. I ſay only *ſmaller* Effect, not none at all, as Mr. *Norman*, *Gaſſendus*, with *Merſennus*, and, as it ſeems, Dr. *Gilbert* alſo found: For they aſſure us, that, upon the niceſt Trials they could make, a Needle weigh'd neither more nor leſs after it was touch'd with the Loadſtone, than it did before. But this was only becauſe their Needles were too ſmall to find that Difference of Weight. For as to my own exacter Trials, my longer Needle of Four Foot, which weighed before 4584 ⅛ Grains; being preſently weighed again, after the Touch, with the ſame Scales and Weights, weighed Two Grains leſs than it did juſt before; and my ſhorter of 3 Feet 11 ⅓ Inches, which weighed before 4015 Grains, weighed afterwards 2 ⅝ Grains leſs: Contrary to all our Expectations. Another Needle alſo of 14792 ½ Grains, and 8 Foot long, which I tried afterwards, loſt 2 ½ Grains; and one ſtill much heavier of 65726 Grains Weight, and 7 ½ Foot long, loſt no leſs than 14 Grains.

Norman's *New Attract.* C. V. Gaſſend. Op. Tom. II. *p.* 129. Gilbert de Magnete, III. 3.

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The Fact is evident; the Needles having been weighed both before and after with the ſame Weights, by our very accurate and skilful Operator Mr. *Hauksbee*. But as for the Cauſe of this Diminution of Weight, I leave it to the further Conſideration of the Inquiſitive; tho' my own Conjecture, as to this matter, will appear under the next Note but one.

N. B. Perhaps Iron is almoſt wholly made up of the *Attractive* Particles; and the Loadſtone of both the *Attractive* and *Directive* compounded together; and probably mixed with other heterogeneous Matter alſo: It having never been purged by the Fire, as Iron has been. And perhaps hence it comes to paſs, that Iron, after it is touch'd by a Loadſtone, and its Virtue excited, will lift up ſo much greater Weights than the Loadſtone it ſelf, which touched it; nay will, upon Contact, take away Needles or Filings of Steel from the ſame Loadſtone; as is well known in Magneticks.

N. B. The Quantity and Direction of Magnetick Powers communicated to Needles, is not properly, after ſuch its Communication, owing to the Magnet which gave the Touch, but to the Goodneſs of the Steel that received it; and to the Strength and Poſition of the Terreſtrial Loadſtone, whoſe Influence alone theſe Needles are afterward ſubject to, and directed by. So that all ſuch good Needles move with the ſame Strength, and point to the ſame Angle, what good Loadſtones ſoever they were excited by,

as

as we have in part already noted. Nor does the *Touch* seem to do much more in Magnetick, than *Friction* in Electrical Cases; I mean, rub off some obstructing Particles that adhere to the inward and outward Surfaces of the Steel, and open the Pores of the Bodies touch'd, and so make way for the Entrance and Exit of such Effluvia, as occasion or assist the Powers we are now speaking of.

N. B. The *Directive* Power of Loadstones seems not to be Immechanical, as Gravity is; but Mechanical, and deriv'd from Magnetick Effluvia, circulating continually round the Loadstone: Of which Circulation there seem to be very evident Indications in Magnetick Experiments; tho' it must be confessed, the Magnetick Effluvia themselves have never yet been rendred sensible, as the Electrick Effluvia begin to be. However, as to the *Attractive* Power, it seems to me as perfectly immechanical as Gravity it self; of which more hereafter.

N. B. No natural Bodies whatsoever are found to hinder, or divert, or retard the Magnetick Effluvia, but Iron or Steel: which still turn the same Lengthways, and receive their Power from them.

II. The Absolute Attractive Power of different Armed Loadstones to support Weights, is, *cæteris paribus*, according to the Quantity, not of their Diameters or Solidities, but of the *Surfaces* of the Loadstones, or in the duplicate Proportion of their Diameters.

This

This Propoſition has been very lately diſcovered by the Right Honourable the Lord *Paiſley*, the great Reviver and Encourager of the Knowledge of Magnetiſm among us: Who upon this Principle alſo has ſo far improv'd the Attractive Power of his beſt *Terrella*, or Spherical Loadſtone, of 1 ¾ Inches Diameter, that whereas it would ſupport little more than 14 Pounds when his Lordſhip bought it; it now ſupports about 22 Pounds. Nor is it any great Wonder, that a Power which acts chiefly on the Surfaces of Loadſtones, and of Iron, ſhould ſtill act in Proportion to thoſe Surfaces.

III. The equal Power of good Loadſtones unarmed, not ſenſibly unequal in Strength, ſimilar in Figure and Poſition, but unequal in Magnitude, is ſometimes a little greater, ſometimes a little leſs, than that of their ſimilar *Diameters*.

This is a Matter of Experiment; and I have found it ſo upon ſeveral Trials. Only the Difficulty is ſo great in determining when quite different Loadſtones, or indeed different Parts of the ſame Loadſtone when ſeparated therefrom, are equally good, that 'tis very hard to come at any degree of Exactneſs in this Experiment.

IV. The Loadſtone equally attracts Needles which have been already touch'd, at a farther Diſtance than thoſe that have not been touch'd; and this at the Diſtance of about 5 to 2; or where its Power is, as we ſhall ſhew preſently, about the Tenth Part of the other.

This has been found ſo upon Trial.

N. B. Both Poles of a Loadſtone do equally attract Needles, till they are throughly touch'd; and then it is, and then only, that the one Pole will begin to attract the one End of Needles, and to repel the other; tho' ſtill the repelling Poles will attract upon Contact, nay at a very ſmall Diſtance, notwithſtanding.

V. The Attractive Power of Loadſtones, in their ſimilar Poſition to, but different Diſtances from, Magnetick Needles, is in the *ſeſquiduplicate* Proportion of the Diſtances of their Surfaces from thoſe Needles *reciprocally*; or as the middle Proportionals between the Squares and the Cubes of thoſe Diſtances *reciprocally*: or as the ſquare Roots of the Fifth Powers of thoſe Diſtances *reciprocally*.

Thus, becauſe 1. 2. 4. 8. are in Geometrical Progreſſion; and the Square Root of $4 \times 8 = 32$. which is nearly, 5,65 is the middle Proportional between 4. the Square; and 8. the Cube of 2: I affirm, that the Magnetick Power of Attraction at *twice* the Diſtance from the Surface of the Loadſtone, is between a fifth and a ſixth Part of that Power at the firſt Diſtance. Thus alſo, becauſe 1. 3. 9. 27. are alſo in Geometrical Progreſſion; and the Square Root of $9 \times 27 = 243$. which is nearly $15\frac{1}{3}$. is the middle Proportional between 9. the Square; and 27 the Cube of 3: I affirm, that the Magnetick Power at *thrice* the Diſtance from

 the

the Surface of the Loadstone, is in the Middle between the Fifteenth and the Sixteenth Part of the same Power at the first Distance. Thus also at 4 times the Distance, the Power will be 32 times as small: At 5 times the Distance, the Power will be almost 56 times as small: At 6 times the Distance, the Power will be a little more than 88 times as small: And if the Distance of one be to that of the other as 7 to 9, the Power at the farthest Distance will be to that of the nearest, as the Square Roots of the fifth Powers, or almost as 130 to 243, and so for ever.

N. B. I here take the Distances, not, as in the Law of Gravity, from the *Centers*; but from the *Surface*: because, as all Experience assures us, the Magnetick Power is chiefly at the *Surfaces* of Loadstones, and of Iron; and indeed seems to have no particular Relation to any Centers at all.

Philos. Transact. N°. 344. Hauksbee's *Experiments*, 2d Edit. p. 322—328.

N. B. That Excellent Mathematician, Dr. *Brook Taylor*, late Secretary of the Royal Society; and Mr. *Hauksbee*, Sen. their Operator, Persons very fit for making such Experiments, have, not long since, at the Society's Recommendation, tried the Power of Three several Loadstones, in order to discover the Law of Magnetick Attraction at several Distances; whose Numbers

are

are extant. But because they made the Experiments without preserving a similar Position of the Line of the Magnet's Motion to the Needles, which was necessary to have been observ'd; the Experiments, how exact soever, have proved of little Use. Nor did either of them in the least hint what Consequences might be drawn from those Observations, in order to discover this Law of Magnetism. I was therefore obliged to make new Observations of my own for that purpose. For tho' the Knowledge of this Law must needs be one of the first Principles of Reasoning in Magneticks, yet has it hitherto been almost entirely neglected. Our great Sir *Isaac Newton* indeed has demonstrated, that such a Power must decrease in more than a *duplicate* Proportion of the Distance; and has intimated, from *some gross Observations*, [possibly he means those above-mentioned: for I know of no others extant] (Col. *Windham* having never published any of his Observations relating to Magnetism at all;) that it decreases in an almost *triplicate* Proportion of that Distance: Yet does the real Proportion, which I have discovered, so considerably differ from both the *duplicate* and the *triplicate*, that these Determinations, which yet are the *best*, if not the *only* ones extant, cannot be acquiesced in, without further Enquiry, and new Experiments: Which Experiments I was therefore obliged to make my self, as they follow presently.

Princip. L. I. Sect. 13. Prop. 85. L. III. *Prop. 6. Corol. 5.*

N. B. In these Experiments, I made use of my Lord *Paisley*'s larger *Terrella*, of 2, 8 Inches Diameter. I generally exposed the *South* Pole of the Stone to the *North* End of the Needle, and that ever so as to keep the Line of the Loadstone's Motion at right Angles with that Needle. I also used sometimes a short Needle of 4; Inches; sometimes a long one of 4 Feet: Both which, till the Loadstone came near the Needles, agreed well enough. But because the Concern of one Pole of the Loadstone with one End of the Needle was most distinct and undisturb'd in the long Needle; and because that Needle afforded Angles more agreeable to Analogy, I preferred the Experiments made thereby. Only at the greatest Distances, the small Needle would be moved when the Weight and Friction of the larger made its Motion scarce sensible. And indeed, I was forced to set down three or four of the farthest Numbers, rather from Analogy to the rest, than from any exact Observations. Nor is the Reader ever to expect greater Accuracy in such remote Numbers than 10′ or 20′, as Mr. *Hauksbee* has justly observ'd, in the Place above referred to. The Reason of which is plain; That there the Friction bears the greatest Proportion to the Magnetick Power of the Needle, and so the most interrupts the Freedom of its Motion.

N. B. The Reader is to remember, that in such Experiments the Force is to be measur'd

by the *Chords* of those Arcs, by which it makes the Needle decline from its natural Direction: To which Chords it is ever proportional; as I have elsewhere demonstrated. I have therefore set down Half the Chords, or the Sines of Half those Arcs of Declination, as the true Measures of the Power of Magnetism.

Mathemat. Philos. Prop. 7.

Distance in Inches.	Degrees of Declin.	Sines of the ½ Arcs.
3	9	
6	0	
6½	90	7071
9	27	2334
12	13	1132
15	9¼	848
18	6¼	588
21	4⅓	392
24	3	262
27	2	174
30	1⅝	160
33	1½	131
36	1¼	109
39	0⅞	73
42	0¾	65
45	0⅝	58
48	0½	44

Now if we take out of this Table the Sines for any Numbers of Inches *double* to each other; as for 9 and 18, they are 2334 and 588; which are nearly as the Squares, or as 4

to

to 1. The Sines for 12 and 24 are 1132, and 269. These are in a greater Proportion than the Squares, or than 4 to 1; but in much leſs than the Cubes, or than 8 to 1. The Sines to 15 and 30 are 848, and 131. These are in a much greater Proportion than the Squares, or than 4 to 1; but in a leſs than the Cubes, or than 8 to 1. The Sines to 18 and 36, are 588 and 109. These are nearly in the Mean, between the Squares of the Cubes, or as 5,65 to 1. The Sines to 21 and 42 are 392 and 73; thoſe to 24 and 48 are 262 and 44; the former a little *under*, and the latter a little *above*, that mean Proportional. The remoter and exacter Diſtances alſo in Mr. *Hauksbee*'s Experiments, at 30 and 60 Inches Diſtance; which gave the Angles of 13°. 20'. and 2°. 15. whoſe Sines of the half Arcs are 1161 and 196, and are very near to the Proportion of 5,65 to 1. So that this *Seſquiduplicate* Proportion appears, by theſe double Diſtances, to be ſtill the true one. The ſame Proportion is more ſenſible, if we take Diſtances *triple* to one another: as 9 and 27. whoſe Sines are 2334 and 174: or 12 and 36. whoſe Sines are 1132 and 109; the one of which is *over*, and the other *under*, that ſeſquiduplicate Proportion; which requires about 15; to 1. That Proportion is ſtill more ſenſible, if we take one Diſtance *quadruple* to the other; as 6; and 26. whoſe Sines are 7071 and 204. or 9 and 36. whoſe Sines are 2334 and 109; or 12 and 48. whoſe Sines are 1132 and 44; the

the first of which *exceeds*, and the other two *want* of, that sesquiduplicate Proportion, which requires 32 to 1. So that the Mean is still on all Accounts this very sesquiduplicate Proportion, and no other.

N. B. Take here the Numbers found at another more accurate Tryal; where many curious and considerable Persons were present.

Dist. in Inches corrected.	Degrees of Declinat.	Sines of ½ Arcs	Ratisesquidupl.
20	2°	175	466.
14 5/8	4	349	216.
13 5/8	6	523	170.
12 5/8	8	697	138.
11 5/8	10	871	105.
10 1/4	12	1045	87.
9 1/4	14	1219	70.

N. B. The Reverend Mr. *Benjamin Worster*, a skilful Mathematician and Philosopher, has proposed another very good Way of finding the Law of Attraction in Magnets, which is built on my Method of comparing Vibrations and Oscillations of Needles with the Oscillations of a Prismatick Pendulum, of the same Radius, moving by the Force of Gravity, and it is well worth our Consideration: *viz.* to count the Number of Vibrations or Oscillations in a given Time at several Distances of the Magnet, and take the Force as the Squares of those Numbers *directly*;

directly: or as the Squares of the Times of an equal Number of thole Vibrations or Oscillations *reciprocally*. Provided only, that that Part of the Force which arises from the Magnetick Power of the Earth, be subtracted from the entire compounded Force, to give the single Power of the Loadstone. According to which Method, we found the Numbers following, upon an exact Trial, made before many curious and considerable Persons; each Experiment being tried thrice over.

20	25	175	466.

N. B. The Needle vibrated once in 3″ 12. being near 4 ⅛ Inch long.

N. B. We used at first Mr. *Rose* the Jeweller's *Terrella*, of 1 ⅛ Inches Diameter.

N. B.

Inches diff.	Numb. Vibr.	Seconds.	So Vibrat. by Magnet alone.	So Vibrat. in Proportion.
1 — 50	in 17 1/2	17"	47	18" — 5.
	in 17 1/4			
	in 16 3/4			
2 — 50	in 24	33 L 7	39	43 L 2 — 1 L 2.
	in 23 1/2			
	in 23			
3 — 25	in 28 1/2	59	33	83 L 3 — 2 L 0.
	in 28 1/4			
	in 27 1/2			
4 — 20	in 29	73	27	135 — 3 87.
	in 29 1/4			
	in 29			
5 — 20	in 35 1/2	88	7	32 — 292 — 3 L 80.
	in 33 3/4			
	in 30			

N. B. We alſo afterward uſed the Lord *Paiſley*'s beſt *Terrella*, 5 Ounces, 16 pw. and 11 Gr. in Weight; and in Diameter 1 1/4 Inch. The Succeſs was as follows.

	in 11 1/2			
1 — 50	in 12 1/2	11 L 5	46	12 L 5 — L 5.
	in 11 1/4			
		[10	47	10 L 6]
	in 21 1/2			
2 — 50	in 21 1/4	22 L 5	43	26 L 2 — 1 L 2.
	in 21			
	in 33 1/4			
3 — 50	in 33	33 L 3	40 L 6	41 L 6 — 2 L 0.
	in 33 1/4			
	in 46			
4 — 50	in 46	46 L 1	36	64 — 2 L 87.
	in 46 1/4			
		[44 L 6	36	62]
	in 45			
5 — 40	in 44 7/8	56	32	87 — 3 L 80.
	in 45			

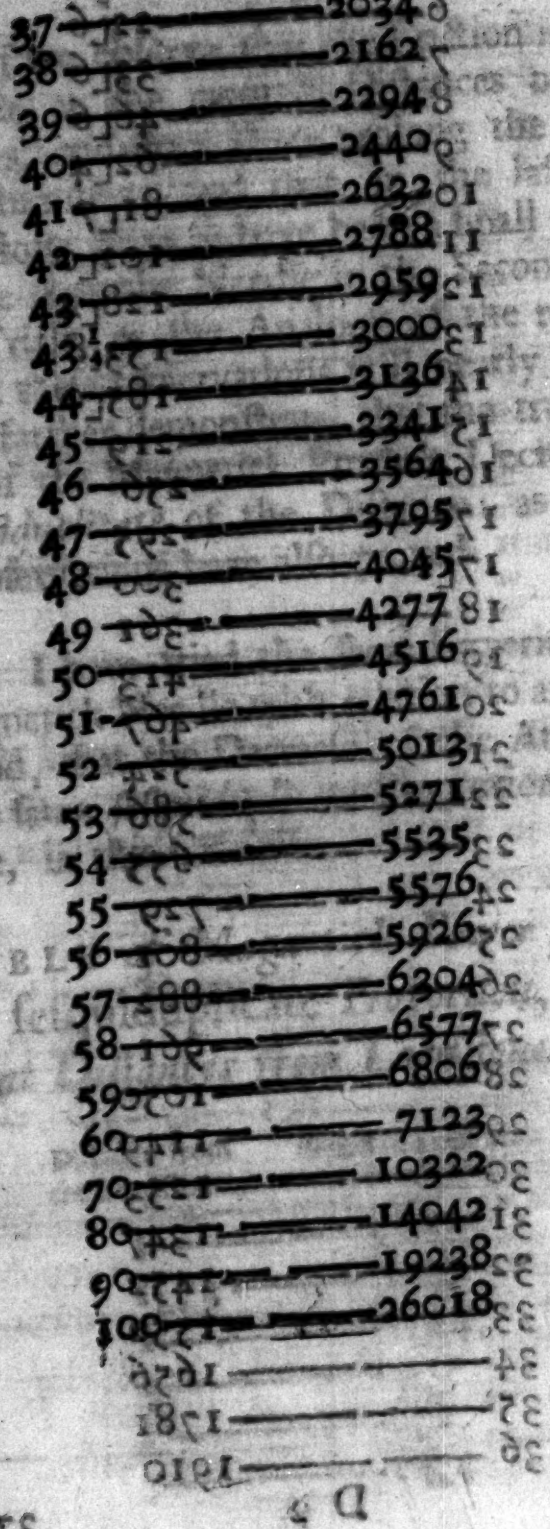
N. B. If we obſerve, that the Friction is moſt conſiderable at the greateſt Diſtances of the Loadſtones, and does there prolong the Time of the Vibrations; and that, in the laſt Set, the Loadſtone ſeems to have been a ſmall matter too remote from the Needle in the Second and Fourth Trials, as the Analogy of the reſt implies; all theſe Obſervations will nearly agree; and will farther demonſtrate, that the true Proportion of the Magnetick Power's Decreaſe, is the *ſeſquiduplicate* of the Diſtance; as all the other Obſervations have alſo proved.

N. B. I have tried the ſame Experiment in one Magnetick Needle with relation to another; and I find, that the Decreaſe of the Attraction is in the ſame *ſeſquiduplicate* Proportion of the Diſtance, in this Caſe alſo.

A Table *of Magnetick Power, from this* ſeſquiduplicate *Proportion, at different Diſtances from Loadſtones.*

Diſtance from the Loadſtone.	Magnetical Power in Proportion.
1	1.25
1.73	1.00
2	1.44
3	4.0
4	8.2
5	14.4

6 —— 225
7 —— 331
8 —— 461
9 —— 625
10 —— 817
11 —— 1025
12 —— 1289
13 —— 1531
14 —— 1851
15 —— 219
16 —— 256
17 —— 295
17½ —— 300
18 —— 361
19 —— 413
20 —— 467
21 —— 524
22 —— 586
23 —— 655
24 —— 729
25 —— 801
26 —— 882
27 —— 961
28 —— 1050
29 —— 1149
30 —— 1253
31 —— 1347
32 —— 1452
33 —— 1552
34 —— 1656
35 —— 1781
36 —— 1910


37 2034
38 2162
39 2294
40 2440
41 2632
42 2788
43 2959
43½ 3000
44 3136
45 3341
46 3564
47 3795
48 4045
49 4277
50 4516
51 4761
52 5013
53 5271
54 5535
55 5576
56 5926
57 6304
58 6577
59 6806
60 7123
70 10322
80 14042
90 19238
100 26018

Corol-

Corollary (1.) If therefore we know the Power of any Loadſtone at any one Diſtance from its Surface, we can readily find it at any other Diſtance. *e. g.* becauſe the Square Root of the Fifth Power of 10 is little above 300. If a Needle of a Foot long, at 5 Inches Diſtance, be equally drawn by Magnetiſm, as by Gravity; (and we ſhall hereafter prove, that the Power of Gravity is, in that Caſe, to the Power of the Magnetiſm of the Earth, as 300 to 1) it will begin to be lifted up at ſomewhat farther Diſtance than half one Inch: Which Experience does alſo atteſt. Thus alſo, if we ſuppoſe a Needle of a Foot long, 10 times ſo near the internal Magnet as we are here; the Power of that Loadſtone there, would be ſomewhat greater than the Power of Gravity here: But of that more hereafter.

N. B. Becauſe the Magnetick Force in Needles of the ſame length ſeems, by the Experiments, to be nearly equal; whether they be larger and broader, or leſſer and narrower towards the Ends; it ſeems as if the Magnetick Effluvia paſſed along the Needle, ſo as ſtill to confine themſelves within its Edges; or by running, like a River, ſo much ſwifter as the Needle or Paſſage is narrower, and ſo much ſlower as it is wider; whereby the Quantity of Motion and of directive Power becomes nearly equal in all thoſe Caſes.

PRO-

VI. A Pendulum, whose Center of Suspension is distant from the Center of Oscillation 39,12 Inches, makes every Swing in the least Arc of a Circle in one Second, or 60″.

This is well known by all that make long Pendulum Clocks; or have try'd Experiments with other Pendulous Bodies.

N. B. I say here, every Swing in the *least* Arc only; for so is the Fact. In Cycloids indeed, the Swings or Oscillations are all exactly equal, be the Arcs never so unequal: But in Circles they are not so: The larger Arcs requiring still a longer Time than the shorter, and the Quadrantal Arc requiring so much more Time than the smallest, as 34 is more than 29; which the famous Monsieur *Huygens* has demonstrated.

VII. A Pendulum, whose Center of Suspension is distant from the Center of Oscillation Four Inches, describes very small Arcs in a little less than one Third Part of a Second, or exactly in 19,2″. And one 32 Inches long in 54″;

This

This is easily found, by extracting the Square Roots of the former Numbers, 39,12, and 4, which are 6,25, and 2. It being well known in Mechanicks, that the Lengths of Pendulums are as the Squares of their Times of Oscillation: Or, which is all one, that the Times are as the Square Roots of those Lengths. Whence the Analogy will run thus, 6,25. : 2. :: 60″. : 19,2″.

VIII. A Prismatick, or Cylindrick Solid and Pendulous Body Six Inches long, swinging about one End as a Center, performs each Oscillation in the same Time with a common Pendulum or Plummet, hung by a Thread of Four Inches; that is in 19,2″. As does also such an one of Four Feet, or 48 Inches long, oscillate in the same time with a common one of 32 Inches long; *i. e.* in 54″, or 19″.

This is well known by the Place of the Center of Oscillation in all Cylindrick and Prismatick Bodies; which is demonstrated to be at $\frac{2}{3}$ of the whole Length: And by Experiments purposely made with such Bodies, which fully confirm that Demonstration.

IX. An Inclinatory or Dipping Needle of Six Inches Radius, and of a Prismatick or Cylindrick Figure, when it oscillates along the Mag-

Magnetick Meridian, performs here every mean Oſcillation in about 6″ or 360‴. And every ſmall one in about 5″ $\frac{1}{2}$, or 330‴. And the ſame Sort of Needle 4 Foot long, makes every mean Oſcillation in about 24″, and every ſmall one in about 22″.

This is a bare Matter of Fact: And I have my ſelf often found it to be ſo upon Tryal.

N. B. I uſe the Words *mean* and *ſmall Oſcillation* here, becauſe in theſe Magnetick Oſcillations, as well as thoſe derived from Gravity, the large Arcs require longer Time than the ſmall ones: And, by my Trials, in the ſame Proportion. So that when we compare their Velocities and Motions together, we muſt take Similar Oſcillations, as I generally take the ſmall ones for my Calculations. And indeed the Equality of the Oſcillations in ſuch Caſes will, on all Sides, be ſecured better, by beginning with thoſe much leſs than 30 Degrees from the true Dip, where they are almoſt equal; than with the largeſt, which are more unequal.

X. The Force of Gravity, or of any uniform Power, in Plains oblique to the Direction of that Power, is always as the Coſines of the Angles made by the Direction of that Power, and the oblique Plain: And the Times in which

which equal Lines are described, are in the subduplicate Proportion of the same.

Thus the Power of Gravity, in which it self tends only along the Perpendicular A C: to accelerate the Body O along the oblique Plain A B, is ever as the Cosine A C, to the Radius A B. and the Times of the Description of equal Lines, as the Square Roots of the same. *Fig.* I.

Thus if A C be one Quarter of A B; the Force along A B, and the Line described in equal Time along A B, will be one Quarter of the Force and Line along A C. and the Times of the Description of equal Lines as 2 to 1. If A C be $\frac{1}{3}$ of A B, the Force along A B, and the Line described in equal Time along A B, will be $\frac{1}{9}$ of the Force and Line along A C, and the Times of the Description of equal Lines, as 3 to 1, and so for ever: As I have demonstrated in my *Mathematical Philosophy*; and as is now well known in Mechanicks. *Coroll.* 2. post Leg. Mot. xxiii.

Corollary (1.) If therefore the same Pendulum, finely Polished, do oscillate both in a Vertical Plain, and upon a Glass Plain, inclin'd to the Horizon, the Times of each similar Oscillation, or of any equal Number of such

Oſcillations, will be to each other reciprocally, as the Square Roots of the Numbers expreſſing the Proportion of the Coſine A C, to the Radius A B. I mean this, with no greater Inequality than muſt ariſe from Friction in the oblique Glaſs Plain, which has no Place in the Vertical Plain. Thus when I tried the Experiment with a Pendulum Four Inches long, which, as we have ſeen, oſcillates in the Vertical Plain, in 19,2″, yet upon a Glaſs Plain ſo inclin'd, that A C was one Quarter of A B, and where, by Conſequence, had there been no Friction, the Time would have been only Double, or 38,4″, it was ſomewhat longer, or above 42‴. Which however is ſufficiently near to this Rule; and is accordingly a real Confirmation of it.

XI. The entire Power of Gravity, is to the entire Power of Magnetiſm, in this Country, as it affects Needles a Foot long, nearly as 300 to 1; and as it affects Needles of 4 Foot long, as 600 to 1.

This is a plain Corollary from the Eighth, Ninth, and Tenth Propoſitions foregoing. For ſince equal Arcs of equal Circles, are deſcribed by theſe Two Powers in unequal Times, which Times are to one another, upon Tryal, in Needles of one Foot long, as 330″ to 19,2″ their Squares, which are 108900, and 368, will give

us

us the Proportion of the Powers themſelves: which is nearly the ſame with that of 300 to 1. And by a like Calculation in Needles of Four Foot long, the Proportion of Gravity to Magnetiſm is nearly as 600 to 1.

Corollary. This Power therefore affects Needles in the ſubduplicate Proportion of their Lengths, reciprocally; and is only of half the ſame Quantity in a 4 Foot Needle; and of one third the ſame Quantity in a 9 Foot Needle.

XII. The Quantity of Magnetick Power accelerating the ſame Dipping Needle, as it oſcillates in different Vertical Plains, is ever as the Coſines of the Angles made by thoſe Plains, and the Magnetick Meridian, taken upon the Horizon.

Let AI repreſent the greateſt Force, along the Magnetick Meridian, as the Semidiameter of a Circle. *Fig.* II.

[A being the Point where the Dipping Needle would cut the Horizon, when it ſtands Perpendicular thereto, and ſwings along the Tangent AB: and I, being the Point in the Line of Sines, applied to the Circle, where the ſame Needle, hanging from the ſame Center, would cut the Horizon in its proper Inclination, along the Magnetick Meridian.]

Let the Angles at A be drawn at Random,

or, for greater Ease, as here, exceeding each other by 15 Degrees. Draw the Chords AC, AD, AE, AF, and AG. Then will Ac, Ad, Ae, Af, and Ag, be the Cosines of the Angles made by the Line of greatest Force AI; and the several Plains, here represented by the Chords AC, AD, AE, AF, and AG. These Cosines therefore, as compar'd with the Radius AI, express the true Proportion of the Power of Magnetism in all these oblique Situations, just as AC expressed that of Gravity along AB, in Proposition X. foregoing.

Corollary (1.) Since the Ascents of the Dipping Needle from the Nadir A, taken along the Circle of the Dipping Needle, must needs increase till they come neatest to the Power at I, *i. e.* as far as c, d, e, f, and g, in that Line of Sines applied to the Circle, which are the Length of the Cosines above-mentioned; At which neatest Points alone, the Needle can rest: 'Tis evident that these Ascents, or Complements of the Dips below the Horizon, will be still in the Proportion of those Cosines respectively.

Corollary (2.) Because the Sine of 30° is half the Radius, the Ascent of the Dipping Needle along the Line, or Plain AD, at 60 Degrees Distance from the Magnetick Meridian AI, will be one Half of the utmost Ascent; and is the most easily tried by every body. Thus,

Thus, because at *London*, the utmost Ascent along the Magnetick Meridian is in Needles of a Foot long 16½, and in one of 4 Foot 14½, the Ascent at 60 Degrees therefrom, on either Side, will be 8°½ in the first, and 7°½ in the second Case, and so every where. Accordingly I have several times tried this Experiment, and always found it to answer the Demonstration, not in that Angle only, but in the others also.

Corollary (3.) If the former Construction be suppos'd in a Plain Perpendicular to the Horizon, upon the same AI, as still the Semidiameter of the same Circle; and it be suppos'd to be plac'd from the Center of the Dipping Needle, along the Magnetick Direction; that so the Sines Ac, Ad, *&c.* may represent the oblique Forces as before: We may thence estimate the Quantity of those Forces, both in the Horizontal and Vertical Situation of Needles: The one exhibiting the Force of the Horizontal Needle; the other of the Vertical Dipping Needle, whose Plain is along the Magnetick *East* and *West*.

Thus, if we would Estimate the Quantity of Force at *London* in the Vertical Plain here mentioned, in Needles of a Foot long, we shall find, that it is to the entire Force along the Magnetick Meridian, as the

the Sine of 73 ¼ to the *Sinus Totus*; or as 96 to 100; and by Conſequence, that their Times of Oſcillation are in the ſubduplicate Proportion of thoſe Numbers; *i. e.* nearly as 98 to 100, or 49 to 50, which agrees to Experience. Thus alſo in Needles Four Foot long, this Force is as the Sine of 75 ½ to the *Sinus Totus*; or as 968 to 1000, and their Times as 984 to 1000.

Thus alſo, if we would eſtimate the Quantity of Force here in the Horizontal Plain, we ſhall find it is to the ſame entire Force above-mentioned, in Needles of a Foot long, as the Sine of 16° ¼ to the *Sinus Totus*; or as 28 to 100; and in thoſe of 4 Foot, as the Sine of 14 ½ to the *Sinus Totus*, or as 25 to 1000, or 1 to 4; and by Conſequence, that the Times of their Vibrations, and Oſcillations, which are in the ſubduplicate Proportion of thoſe Numbers; are, in the firſt Caſe, as 52,9 to 100; and in the laſt, as 500 to 1000, or 1 to 2, or as 11½ to 6″; which alſo agrees to Experience.

N. B. The Power by which all Horizontal Needles are governed, and all our Navigation directed, in theſe Parts of the World, is but one Quarter of the Power by which the Dipping Needle is moved, and

and the Longitude and Latitude of Places are now propoſed to be diſcovered.

Corollary (4.) Hence we learn a new and ſure way of finding the true Angle of Inclination of the Dipping Needle, even without immediately obſerving it; and that by one ſingle Analogy, thus: As the Square of the Time of any Number of Vibrations in the Horizontal Plane, to the Square of the Time of the ſame Number of Similar Oſcillations in the Vertical Plane, along the Magnetick Meridian: So is the *Sinus Totus*, to the Coſine of the Angle of Inclination.

Let us ſuppoſe that our Needle be one Foot long, and that 100 of theſe mean Vibrations are to 100 Similar Oſcillations; or, which is the ſame thing, one Vibration to one Oſcillation, as $11''\frac{1}{3}$ to $6''$; or that the ſame Needle, when playing horizontally, takes up $11''\frac{1}{3}$ in one Vibration, and when playing Vertically takes up but $6''$; Then will the Analogy run thus: $11''\frac{1}{3}q$: $6''q$ :: 128 : 36 :: 100 = Rad : 28 = Sin. $16^{\circ}\frac{1}{2}$.

Thus alſo, as the Square of $86\frac{1}{2}'$, the Time of 2 ſmall Vibrations in an Horizontal Needle of Four Foot long, to the Square of $44''$, the Time of the like Number of Vibrations of the ſame Needle uſed as a

Dipping Needle: So is 10000=Radius: to 2560=Sine 14° ½. And ſo in all other Caſes whatſoever.

N. B. Altho' it may be convenient to count the Oſcillations and Vibrations by a Pendulum of 9,8 Inches long, which gives half Seconds preciſely; yet will any other Pendulum, either longer or ſhorter, do, in caſe it be equally uſed with both the Vibrations of the Horizontal, and the Oſcillations of the Dipping Needle.

N. B. Theſe Oſcillations in Dipping Needles, muſt be made without their Poizes; and about the Place where they dip naturally; or where the Magnetick and the other Power are in a perfect Equilibrium: Nor muſt the Angle be taken above 6 or 7 degrees on either ſide; leſt the Mixture of the other Power too much diſturb the Vibrations.

N. B. Where the Angle of Inclination is leſs than 45°, it will be beſt to find its Complement, the Angle of Aſcent, by comparing the Oſcillations along the Magnetick *Eaſt* and *Weſt*, with thoſe along the Magnetick Meridian: Which will be done by the foregoing Analogy.

N. B. If the Power of Magnetiſm were as nearly the ſame every where on the

Earth's Surface, as is that of Gravity, the forementioned Angle might be found by the Horizontal Needle alone, from the same Analogy. The First and Third Terms in that Case being standing Quantities; and there being Occasion for nothing but counting the Number of Seconds in an equal Number of Vibrations of the Horizontal Needle. However, this Method by Calculation ought every where to be put in Practice, together with the direct Observation of the Dip it self; that so the Angle may be confirm'd, or, on any Error happening therein, corrected, for the greater Security of Navigation.

N. B. One easy way of discovering the true Angle of Inclination in long Needles, is to observe the Needles Oscillations by a Plummet or Watch that shews half Seconds, when they are not above one Degree wide; and to note that Point for the true Dip, where the Arcs and Vibrations of the same Number of half Seconds on each Side meet in the Middle; for there both the Arcs and Times are in a manner equal on both Sides; and the Middle of that entire Arc and Time gives the true Angle of Inclination.

Corollary (5.) Since the Horizontal Needle is moved only by a Part of the Power which moves the Dipping Needle; and that it only points to a certain Place in the Horizon, because that Place is neareſt its Original Tendency; whenever the Dipping Needle ſtands exactly perpendicular to the Horizon, the Horizontal Needle will not reſpect one Point of the Compaſs more than another, but will wheel about every way uncertainly.

And whereever it happens that this Needle does ſo, as it has ſometimes done, it is evident the Dipping Needle is there exactly perpendicular to the Horizon: Though indeed that perfect Equilibrium, ariſing from ſuch an exact Perpendicularity, can reach but to a very ſmall Compaſs of Ground; and ſo muſt be a very rare thing in Obſervation.

XIII. The Times of Oſcillation and Vibration, in Dipping and Horizontal Needles, equally good, is that of their Lengths directly: and the actual Velocity of their Points along their Arcs always equal. Thus, the Time of a ſmall Oſcillation in both my Needles, of one Foot long, was about 5″½; and the like Time in both my Needles of 4 Foot long, is about 22″. which Numbers are as 1 to 4; and conſequently the Points move a fourfold Arc in fourfold Time, and an equal Arc in equal Time.

N. B. Becauſe ſome Steel takes a better Touch than others; and ſome Needles do thereupon conſiderably differ from this Proportion, tho' they all keep the ſame Angle of Direction; This Rule muſt be taken with that Limitation.

Corol. (1.) Hence Magnetick Needles are, *cæteris paribus*, ſtill better the longer they are; and that in the ſame Proportion with their Lengths. For ſince their Points for Obſervation move along their Arcs with equal Swiftneſs in all Caſes; and thoſe Arcs are ſo much exacter, as their Semidiameters are larger; it follows, that Needles are ſo much the better, as thoſe Semidiameters, or, which is all one, their Lengths and Diameters are larger. Thus, a Dipping or Horizontal Needle of Four Foot long, is four times as good as thoſe One Foot long: And thus thoſe of 8 Foot will be twice as good as thoſe of 4, and ſo on.

Coroll. (2.) Hence the Longitude and Latitude, if they depend on Magnetick Needles, may be found to what Degree of Exactneſs we pleaſe: there being, that I find, no more a Limit in Nature in the Caſe of Magnetick Needles, than in that of Aſtronomical Inſtruments: Which are alſo known to be better, *cæteris paribus*, in exact Proportion to their Semidiameters.

XIV. A Dipping Needle of a Foot long will plainly ſhew an Alteration of the Angle of Inclination, in theſe Parts of the World, in half a Quarter of a Degree, or 7 ½ Geographical Miles; I mean this, if we go along, or near to a Meridian.

The former Part of this I have found my ſelf upon Trial, in travelling the laſt *Autumn* from *Lincoln* to near *Oxford*; and the ſame, or a greater Exactneſs, appears practicable not only from my own Obſervations here with Needles of 4 Foot, but alſo from thoſe in Mr. *Norman* and Mr. *Bond*, when there were good Needles, and Care was taken to be accurate in the Obſervations.

N. B. If therefore this Alteration be viſible in theſe Parts of the World, along or near a Meridian, within ⅛ of a Degree, or 7 ½ Miles, with Needles of one Foot: and within 2′ or 3′ or Miles with thoſe of 4, where yet the Dipping Needle alters not nearly ſo faſt as the Latitude; or where we muſt go above 100 Geographical Miles, for the Difference of 75′: Such an Alteration will be viſible in a much leſs Space of Ground, in moſt other Parts of the World: Where 'tis not only common that the Minutes of the Dipping Needle alter as faſt as the Geographical Miles of Latitude, but that, in

the Torrid Zone eſpecially, thoſe Minutes alter much faſter than the other; as will appear hereafter.

Corollary. Hence it is plain, that the Latitude may generally with Eaſe be diſcovered by the Dipping Needle, though it be no more than a Foot long, when we travel along or near a Meridian, more nicely than to $7' \frac{1}{2}$, or Miles, and that it may be diſcovered with the like Eaſe, by one of Four Foot, as near as 2′ or 3′, or Miles; that is, much nearer than it is now uſually known at Sea by Celeſtial Obſervations.

XV. A Dipping Needle of Four Foot long, in theſe Parts of the World, will ſhew an equal Alteration along a Parallel, that one of a Foot long will ſhew along a Meridian: That is, This will with equal Exactneſs ſhew the Longitude, as That the Latitude, both by Sea and Land.

This depends upon the Poſition of the *Lines of equal Dip*, in theſe Parts of the World; which are found, upon Tryal, to lie about 14 or 15 Degrees from the Parallels: Or where the intercepted Parts along a Meridian, are about one quarter of thoſe along Parallels: As the View of my ſmall Map hereto prefixed, which is made from the beſt Obſervations, will readily demonſtrate.

Corol-

Corollary (1.) Since therefore we can obſerve an Alteration in the Dipping Needle of one Foot long, when we go nearly *North* and *South*, in $7\frac{1}{2}$, Geographical Miles Space; we can do the ſame with one of Four Feet, when we go *Eaſt* or *Weſt*: *i. e.* We can by ſuch a Needle diſcover our Longitude to half a quarter of a Degree, or $7\frac{1}{2}$ Miles, even here, and much nearer in other Parts of the World.

Corollary (2.) Since, as we have ſhewn, we can have Needles of 5, nay 6, 7, 8, or more Feet long; which will move with Strength ſufficient for exact Obſervations: And ſince, by the Uſe of Microſcopes, in viewing the ſmall Diviſions of Degrees on the Limb of our Inſtrument; we can ſtill greatly improve the Exactneſs of ſuch Obſervations; It is evident, that it is no way impoſſible, with moderate Care, to diſcover, at Land, by a Dipping Needle, our Longitude, nearer than to Four Miles.

Corollary (3.) Since many Obſervations have been already made at Sea, and on Shipboard, with Dipping Needles, by Mr. *Hudſon*, Mr. *Noel*, Mr. *Pound*, Mr. *Cunningham*, Monſieur *Feuillee*, Col. *Windham*, and others; which have determined the Dip uſually within a Degree; ſometimes within one half, or one third of a Degree, or nearer; *i. e.* about half

half as exactly as at Land; and this with ſmall Needles of 5 or 6, or at the moſt 9 Inches long: 'Tis evident, that at the ſame Rate, and with the like Care, we may determine this Dip, even at Sea, much nearer than to half a quarter of a Degree, and the Longitude uſually ſtill nearer; even without any farther Improvements of the way of making ſuch Obſervations there: Which yet are juſtly to be expected, when the Conſequence of ſuch Exactneſs ſhall appear to be ſo very conſiderable. Nor do I hereby determine, how much greater Accuracy may ſtill be expected from that very exact Way before-mentioned by the Number of Vibrations, or by better avoiding the Shaking of the Ship; but here compute the Nearneſs that may be arriv'd at by a common Obſervation of the Angle of Inclination it ſelf only.

XVI. Needles, Inclinatory or Horizontal, when touch'd with Loadſtones, of whatſoever Kinds, of whatſoever Country, of whatſoever Strength, and in whatſoever Parts of the Loadſtones, do all tend exactly to the ſame Points, whether of Dip or Variation, reſpectively.

This is not only clear from the Nature and Cauſe of thoſe Directions, which as they muſt be ſingly deriv'd from one and the ſame internal Loadſtone of the Earth, and its Effluvia, of which preſently, and muſt, therefore, all of them, be affected thereby in the ſame manner;

but

but from direct Experiments. Which take in the Words of Mr. *Norman*, for the *Inclinatory*; and of Mr. *Sellers* for the *Horizontal Needle*; as follows. "All these Stones, "[of several Countries] says *New Attract.* c. 1. "Mr. *Norman*, are different one "from another, as well in Force, as "in Colour and Weight; yet all of one Opera- "tion in the Needle, shewing one Point At- "tractive; as I have proved my self by three "sundry Sorts of them, which I have. To "this Dr. *Gilbert* also agrees. *Gilbert de Magnet.* V. 5. And, says Mr. *Seller*, "I have *Philos. Transact.* N°. 23. "often made Trial with many "Needles, touching them in each "Hemisphere of the Stone, with all Variety "of Ways I could imagine, to find, if it were "possible, by that Means to cause any of those "Needles to vary in its Direction; but all of "them conform'd to the Magnetical Meridian; "standing *North* and *South*, as other Needles "that were touch'd upon the very Pole of the "Stone. All Needles touch'd upon different "Loadstones of several Bigness, and different "Virtue, in all Parts of the World, agree in "this Magnetical Harmony, that they all give "the same Directions.

XVII. The Earth upon which we live, includes within it a vast Spherical Magnet, concentrical thereto; with its own Poles, Meridians, Equator, and Parallels: And all much of the

the ſame general Nature with thoſe ſmall *Terrellæ*, or Spherical Loadſtones, which are in the Poſſeſſion of the Curious with us.

That this is true in general, no one can deny, who has duly conſidered the known Phænomena of the *Direction*, *Variation*, and *Inclination* of all Needles, touched with a Loadſtone, in all the ſeveral Parts of the World: Which are indeed, in a manner, the very ſame which ſuch Needles exhibit to us, not only on ſuch a Magnet's own Surface; but on the Outſide, nay at a good Diſtance from, any Caſe, or Box, wherein ſuch a *Terrella* or Spherical Loadſtone is included. Nor is the Evidence for the one much different from, or inferior to that of the other. I mean at leaſt in ſuch Circumſtances, where the Spectators are not permitted to open the Caſe, or Box, and ſee the Magnet it ſelf within: Of whoſe Preſence yet they may be abundantly ſatisfied by thoſe Phænomena, without ſuch ocular Demonſtration. And that this Loadſtone is concentrical to the Earth, and Spherical, farther appears by the invariable Situation of the Earth's Center of Gravity, notwithſtanding this Loadſtone's perpetual Alteration of Place; of which preſently.

XVIII. The Power of a good *Terrella*, or Spherical Loadſtone, as it affects a Needle of a Foot long, is equal to the Magnetick Power of that internal Loadſtone, about 2 ½ or 3 Diameters of ſuch Loadſtone.

In order to demonstrate this, the Reader must remember, that we have prov'd, that the Magnetick Power of the Earth, or internal Loadstone, on Needles of one Foot long, is nearly the 300th Part of the Power of Gravity with us: And must observe, that the Chord of 16′ is nearly the 300th Part of the Chord of 90; or that the Power of a Magnet, when it can draw a Needle, hung by a Thread perpendicularly, to 16′ from that Perpendicular, is equal to the 300th Part of our Power of Gravity. This being suppos'd, the Proposition will be soon prov'd by the Experiments following.

Prop. XI. *prius.*

The Lord *Paisley*'s larger *Terrella*, of 2 L 8 Inches diameter, draws a small Needle 16′, or a full Quarter of a Degree from the Perpendicular, at the Distance of about 5 Inches; and his smaller, but vastly stronger *Terrella* of 1 ¼ Inches Diameter, draws it as far at about 7 ½ Inches. So that by Consequence the former would affect a Needle of one Foot long equally with the Power of Gravity, at about 4 Inches Distance, or at about 1 ½ of its Diameter: and the latter at about 6 Inches, or at about 3 ½ of its Diameter. So that our Determination of the Distance of a Foot Needle from any Spherical Loadstone, when its Force is the 300th Part of our Power of Gravity, must be suppos'd, by the Experiments hitherto made, to be, in a Mean, about 2 ½ or 3 Diameters of that Loadstone.

Corol.

Corol. (1.) Upon this Hypotheſis we may determine the Quantity of Magnetick Attraction at all Diſtances from the internal Loadſtone; and that by the Uſe of the Table, *p.* 22, 23, 24. above, for Needles of a Foot in Length. For the Column of the Powers will ſhew the Proportion of thoſe Attractions, at all ſuch Diſtances: *e. g.* Let us ſuppoſe the Surface of our internal Loadſtone to be at the Diſtance of 3400 Miles from the Earth's Surface; I deſire to know in what Proportion the Magnetick Power, upon a Needle of a Foot long, is ſtronger 2900 Miles deep, or about 500 Miles Diſtance from the Surface, and about 1060 Miles from the Center of the Earth; I mean as compar'd with that Power here, or with the 300th Part of our Power of Gravity. The Diſtances therefore being nearly as 1 to 7, the Number over-againſt $43\frac{1}{3} = 300$, is to the Number over-againſt $\frac{1}{7}$ of that Number or $= 6\frac{2}{3}$, or $\frac{10}{24}$, as 300 to $\frac{10}{24}$. So that at ſuch Diſtance the Power of the internal Magnet, inſtead of being, as here, only the 300th Part, is between the half and the third Part of our Power of Gravity: And the Calculation is alike for all other Diſtances, and all other Lengths of Needles, whatſoever.

N. B. If we then take the Proportion of the Diameters for the true one of equal Force, and ſuppoſe that the Power is the ſame we here find it at thrice the Length of its

y'n Diameter from its Surface; this Diameter of the internal Loadſtone muſt be about 1150 Miles, and its Semidiameter 575 Miles; as every one will readily find upon Calculation.

Corol. (2.) Since Sir *Iſaac Newton* has demonſtrated, that the Power of Gravity diminiſhes within the Earth; and is nearly leſſer there, than at its Surface, in the Proportion of its greater Nearneſs to the Center: That Magnetick Power, at 2900 Miles Diſtance from us, and nearly 1060 from the Earth's Center, which is $\frac{1}{4}$ of the Power of Gravity here, will be ſomewhat greater than the Power of Gravity there. A little above which Place therefore, is a Limit well deſerving our Attention; it diſtinguiſhing the reſpective Quantity of the two Powers in the ſuperior and inferior Regions: In the former of which, Gravity is ſtronger than Magnetiſm; and in the latter, Magnetiſm is ſtronger than Gravity: I mean as it affects Needles of one Foot Diameter.

Princip. L. 1. Prop. 73. & L. III. Prop. 9.

Corol. (3.) At that Limit, near the Magnetick Poles at leaſt, Iron of a Foot long will be twice as heavy, or fall twice as faſt, as any other natural Body whatſoever, *viz.*, by the Union of theſe two equal Powers, Gravity and Magnetiſm: And by Conſequence, above that Limit, ſuch an Iron will be leſs than twice as heavy: below it, more than twice as heavy as all other natural Bodies whatſoever.

XIX. The Earth's internal Loadstone is not fixed to our upper Parts, but is, respectively thereto, moveable; and actually revolves, upon the Earth's Axis, from *East* to *West*, in a certain long Period of Time.

This our Learned Dr. *Halley* has proved beyond reasonable Contradiction, from the constant *Variation of the Variation* of the Horizontal Needle *Westward*; and it may be confirm'd by the still more regular Increase of the Inclination of the Dipping Needle here at *London* also: Where alone it has been long and accurately known; while *A. D.* 1576. it was here 71° 50′, as Mr. *Norman* himself assures us: Where it was about 24 Years afterward almost 72°. as Mr. *Wright* assures us: Where, *A. D.* 1613. it was between 72° and 73°; but neareſt 72°, as Dr. *Ridley*'s Two Schemes of the Dipping Needle, with one of his Tables of its Inclination, imply: Where it was, *A. D.* 1676. about 73°. 30′. as Mr. *Bond*'s Scheme of the Dipping Needle informs us: And where it was the last Year, and is this, by a Needle of one Foot, not pois'd, 72°. 45′. but by one of 4 Foot pois'd above 75. (which is also the true Dip of the smalleſt Needles;) as I have my self frequently and exactly observed. Only it must

Philos. Transact. N°. 148.

New Attract. C. IV. VII. Gilbert de Magnete: Encomium Ridley *of Magnetick Motions*, C. 35, 39, 40.

muſt be particularly remark'd, that this Revolution of the internal Magnet from *Eaſt* to *Weſt*, is not abſolute or real; but reſpective only: that is, it revolves not yet quite ſo faſt from *Weſt* to *Eaſt*, as does the upper Earth on which we live. Which ſlower Motion one way, muſt needs occaſion with us a reſpective or apparent Motion the other way; as every one will readily underſtand, upon the leaſt Conſideration.

Corol. (1.) Hence it is clear, that the Diurnal Motion belongs to the Earth, and not to the Heavens. For we ſee here, that Part of this abſolute Diurnal Motion from *Weſt* to *Eaſt*, remains yet uncommunicated to the internal Central Loadſtone: and is indeed the proper Occaſion of its reſpective Diurnal Motion from *Eaſt* to *Weſt*, to this very Day.

Corol. (2.) Hence it is evident, in Dr. *Halley*'s own Words, "That the only
Philoſ. Tranſact. N°. 148. "Way to render this Motion in-
"telligible and poſſible, is to ſup-
"poſe it poſſible to turn about the Center of
"the Globe; having its Center of Gravity
"fix'd and immoveable in the ſame common
"Center of the Earth: And that this moving
"internal Subſtance is looſe, and detach'd from
"the external Parts of the Globe; and may
"well be reckon'd as the Shell, and the internal
"as a *Nucleus* or Inner Globe, included within
"ours; with a fluid Medium between": Exactly

actly as I had collected from the other *Phænomena* of Nature, compar'd with the *Moſaick* Hiſtory of the Creation, long ago, in my *New Theory of the Earth.*

Corol. (3.) Hence alſo, in the ſame Dr. *Halley*'s own Words, 'tis plain, Ibid.

"That this Motion is *Weſtward*:

"And, by Conſequence, that the aforeſaid "*Nucleus* has not preciſely attained the "ſame Degree of Velocity with the exte-"rior Parts in their Diurnal Revolution; "but ſo nearly equals it, that in 365 Revolves "the Difference is ſcarce ſenſible: And that "this, moſt probably, has ariſen from the "Impulſe, whereby this Diurnal Motion was "impreſs'd on the Earth; being given to the "external Parts, and from thence, in time, "communicated to the internal": Exactly alſo as I had aſſerted in the ſame *New Theory.*

Corol. (4.) Since therefore the Communication of the Diurnal Motion from the external to the internal Parts of the Earth, appears to be mechanical, and done gradually, according to the Laws of ſuch Communication of Motion among Bodies; it is alſo moſt probable, that this firſt Impreſſion on the external Parts of the Earth was alſo mechanical, and done by the oblique Impulſe of ſome other Body: Which is the only Way of impreſſing ſuch a Diurnal Rotation from one Body to another.

Corol.

Corol. (5.) Since therefore no other Bodies in the Visible Universe are capable of approaching to, and Obliquely impelling any of the Planets, but only the Central Solids of Comets; which indeed continually pass through the Planetary System; and, as Dr. *Halley* truly says, may make a *Collision* with these Planets: 'Tis most probable, that this Diurnal Motion, thus mechanically impress'd on the outer Earth, was deriv'd from no other Cause than the oblique Collision of a Comet: as I have also long since conjectured, in the same *New Theory*. Which will be farther confirm'd hereafter, when we come to calculate the Velocity of this Diurnal Rotation, and to compare it with the Velocity of Comets.

Halley de Cometis. In calce.

XX. This internal Magnet has one *Central Pole, Northwards*, in the Nature of the Poles of our common Loadstones. But its *Southern* Pole appears not to be *Central*, but *Circular* rather; and that at a great Distance from the *Southern* Pole of the Earth.

This is proved, as to the former Part, by the Famous Mr. *Hudson's* Observations, made *A. D.* 1607, and 1608. of the Inclination of the Dipping Needle, in one of his *Northern* Voyages: Whence it appears, that he once, about the

Purchas Pilgrim. Vol. III.

the Latitude of 75°. 22′. came within about ½ Degree of the *Northern* Magnetick Pole; or near 89°. or 89°. ½ Inclination of the Dipping Needle below the Horizon: And that he twice came to the same Dip of 84°. at the Distance of about 12 or 13 Degrees of a great Circle; once before he came to the *North Cape*; and again afterward, at *Nova Zembla*.

The other Part of this Proposition is proved by *Pere Noel*'s Observations, in his Voyage to the *East Indies*, *A. D.* 1706. where it is evident that his Ship sailed, about 1200 Miles together, very near the same Dip of 89° ½ and 90°. or near the same *Southern* Magnetick Pole. As also by Monsieur *Feuillée*'s Observations beyond *South America*: Which do, by Analogy, imply that the Polar Inclination of 90°. had he proceeded to make Observations sufficiently *Southwards*, would have fallen in or near the very same Circle also. As the Lines of equal Dip, drawn by me, from all the best Facts yet published, or by Analogy to them, upon Mr. *Molyneux*'s Terrestrial Globe, will demonstrate.

Printed at Prague.

Printed at Paris.

XXI. The *Northern* Magnetick Pole is situate now about the Latitude of 76° ½, or 13° ½ from the *North* Pole of the Earth; and about 30°. *Eastward* from the Meridian of *London*.

This is proved several ways; as *by* Mr. *Hudson*'s Observation of the Dip of 89° ½. which, upon Allowance made for that Pole's Motion since, comes near this Point: *By* the Intersection of the Meridians to that Pole, which are the Perpendiculars to the Magnetick Parallels of equal Dip in the Map hereto belonging, and intersect the Parallel of 76° ½ about this very Point: *By* the Alteration of the Variation of the Horizontal Needle, an entire Point of the Compass, or between 11 and 12 Degrees, in a very small Distance; particularly noted thereabout by one that accompanied Mr. *Hudson*, when he went the *Northern* Voyage already mentioned. And, lastly, *by* the remarkable Circumstance, noted near that Place by a *Dutch* Sailor, that the Compass, or Horizontal Needle, fail'd them there, as to its usual Direction; and would turn to any Point of the Horizon indifferently: Which could only happen over the very Magnetick Pole it self.

Vid. De Stair Physiolog. p. 487.

XXII. The *Southern* Magnetick Circular Pole has its Center, or Central Pole, nearly in the Parallel of 60°. or at 30 Degrees from that Pole: And in a Meridian passing along the *East* Coast of *Borneo*, about 117°. *Eastward* of *London*. Its Radius is also an Arc of a great Circle, of about 44 Degrees.

These

These are natural Consequences from *Pere Noel*'s and Monsieur *Feuillee*'s Observations, already mentioned; especially when they are placed rightly on a Terrestrial Globe; and when the Center of that Circular Pole is justly determined.

N. B. Mr. *Benj. Worster*, already mentioned, is possess'd of a Loadstone that gives great Light to this Linear or Circular Pole: For it has both its Edges or Lines Polar; without any such single Central Pole therein, as we ordinarily see in other Loadstones. Nor are we, who live in the *Northern* Regions, which have an internal Central Pole, and no other, so likely to have many Loadstones of the Linear or Circular Sort, as the *Southern* People; who alone have any such Linear or Circular Magnetick Pole within the Earth.

N. B. The Situation of this *Southern* Circular Pole, which is very oblique to the *Axis* of our *Northern* Part of the internal Loadstone, must needs greatly diversify the Length of the Magnetick Meridians; and cause an uncommon Position to the Magnetick Equator and Parallels, from those in our ordinary *Terrellæ* or Spherical Loadstones. The oblique Section of a Cone, or Egg, will give us some tolerable Representation of the special Position of these Lines. But this will best be understood from the View

of the ſeveral Magnetick Poles, Parallels, and Equator, on Mr. *Molyneux*'s Terreſtrial Globe; which I have drawn according to the beſt Facts and Obſervations: and to which I muſt refer the Inquiſitive Reader.

N. B. This great Inequality of the Meridians of the internal Magnet ought the leſs to be wondred at, ſince we ſee Inequalities of the very ſame Nature in our *Terrellæ* or Spherical Loadſtones here: Their Equators being by no means equidiſtant from their two Poles, but ſomewhat oblique to their Axes; as Experience ſhews.

XXIII. *Problem.* To find the Velocity of the reſpective Motion of the Magnet within the Earth; or particularly of its *Northern* Pole.

Let P repreſent the *North* Pole of the Earth: L *London*: PB an Arc of the Meridian of *London* of 13° ½. BL the remaining Arc of that Meridian of 25°. BCRD the Parallel along which the Pole of the Magnet revolves from *Eaſt* to *Weſt*, or from D towards B. C the Place of the Magnet's Pole now, determin'd, as above, at 30 Degrees from B. Or where the Line LCE makes with the Meridian of *London* an Angle of about 14 Degrees; and ſo cuts its Parallel at 30° Diſtance from the former

Meridian. Now in order to discover the Place of the Magnetick Pole 144 Years ago; and, by Consequence, to discover the Arc DC described in that Term of Years, we have these *Data*: That the Dip from Mr. *Norman*'s and my own Observations, was then 3° 40′ of the Magnetick Inclination, or 5½ of a great Circle of the Earth less than it is now: Or that CE + CL = 27,7 + 5,5 = DL = 33,2.

Draw therefore the Arc ED from the Center L; and with the Radius LE. That Arc will cut the Parallel BCRD in D, the Place of the Magnetick Pole at the former Time: Whereby we truly discover the Point D, where the Pole was *A. D.* 1576, or 144 Years ago; and, by Consequence, the Arc CD, which that Pole has gone in the same Interval. Which therefore appears to be full 27°. 0′. or that it goes forward above one Degree in 5 Years, or an entire Revolution

volution in 1920 Years; which is much ſlower than Mr. *Philips*, Mr. *Bond*, or Dr. *Halley* have ſuppoſed.

N. B. That the Alteration of the Variation in the former 72 Years of that Term, was to the ſame Alteration in the latter 72 Years, (as Dr. *Halley*'s Table of thoſe Obſervations ſhews) nearly as 10°. to 14°. Which is, in general, here agreeable to the natural Inequality of the Angles DLR and RLC, whoſe Arcs DR and RC are equal.

Philoſ. Tranſact. N°. 148.

Corol. (1.) As the Number of Days in the Upper Earth's Diurnal Revolution, to the Number of Days in the Revolution of the internal Magnet; or as 1 to 700000; ſo is the reſpective Motion of this Magnet from *Eaſt* to *Weſt*, to the real Motion of the Upper Earth from *Weſt* to *Eaſt*: or, to ſpeak ſtrictly, ſo is the Difference of their Motions from *Weſt* to *Eaſt*, to the entire Motion of the Upper Earth the ſame way.

Corol. (2.) This external fixed Earth has therefore communicated almoſt all its Motion already to the inward and moveable Parts; and can communicate no more than this Difference of their Motion; and that only in an infinite Term of Years: Or, in other Words, this real internal Motion can never be the 700000th Part ſwifter than it is at preſent.

Corol.

Corol. (3.) This internal Motion therefore began upon the Commencement of the Diurnal Motion of the upper Earth; or as ſoon as there were Days and Nights, in Diſtinction from Summer and Winter; and has gone ſtill faſter and faſter, by the Communication of that Diurnal Motion of the upper Earth, through the intermediate Fluid, to the internal Magnet, in all the paſt Ages of the World, ſince it came into its preſent State.

Corol. (4.) Since therefore, by Sir *Iſaac Newton*'s Third General Law of Motion, Action and Reaction are ever equal, and tend to contrary Parts; this internal Loadſtone, thus accelerated by the upper Earth, muſt have all along retarded that upper Earth, and made the Diurnal Rotation, or the true Duration of each Sydereal Day, ſtill ſlower and ſlower; and this ever ſince the Commencement of that Diurnal Rotation. Princip. p. 13. Ed. 2.

Corol. (5.) The Length of a Sydereal, and, by Conſequence, of a Solar or common Day, has been therefore ſomewhat different in all the paſt Ages, ſince the preſent State of the World began: And the ſame annual or menſtrual Periods muſt anciently have contained more, and of late fewer Days, the one than the other.

Corol.

Corol. (6.) This Acceleration on one Side, and Retardation on the other, was very great at the first Beginning of the Diurnal Motion; when the Difference of their Motions was equal to the entire Motion it self; but must become less and less, as the one went slower, and the other faster; and thereby their Difference of Motion, which is the sole Cause of this Acceleration and Retardation, became less and less continually. So that as they began, in Proportion to their Quantity of Matter, to affect each other; so the same Quantities continuing of each Side, must have gone on to affect one another in the same Proportion: *i. e.* the entire Impressions on both Sides, or the Difference of those Motions, must have been all along in a Geometrical Progression.

Corol. (7.) If therefore we knew, *a priori*, the exact Proportions of the Quantity of Matter in the upper fixed Earth, to the moveable internal Fluid and Magnet; with the Nature of the Surfaces above and below the Fluid, and the particular Quantity and Tenacity of that Fluid; it would be possible, from the known Difference of their Velocity now, which is nearly as 1 to 700000 to go backward, and find those Differences and Quantities of Motion themselves, *à priori*, in all the past Ages; and so geometrically or mechanically to determine, how long it has been since this Difference of

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the Diurnal Revolution from a Circle vaniſhed away, and the internal Loadſtone had no Diurnal Motion at all. Nay, if we any way knew the Velocity of the firſt Diurnal Rotation of our upper Earth it ſelf, we might then geometrically or mechanically determine, *à priori*, how long ago that Rotation began; or how ancient the preſent State of our Earth was.

Corol. (8.) However, ſo far we are ſure, that the Earth on which we live has not been from all Eternity, in its preſent State; but at a certain Period backward, this Diurnal Motion, or our Day and Night, as diſtinct from Summer and Winter, really began; as all ancient Tradition and Records whatſoever do agree; and as Dr. *Halley* himſelf is very free to confeſs. *Philoſ. Tranſact.* N°. 344.

Corol. (9.) Nor is this Geometrical or Mechanical Method of determining the Origin of our Diurnal Motion, capable of the Suppoſal of thoſe 365000, or any like vaſt Number of Years, which ſome Pagan Nations pretend to have Traditions about. For no Geometrical Series can be taken, conſiſtently with the Phænomena of Nature, which can admit any thing like thoſe extravagant Numbers; nor can we ſhew any thing like ſuch a parallel Velocity of a Diurnal Rotation, as muſt then have obtained at firſt, in the whole Univerſe. If any of theſe Numbers had been true, the firſt Diurnal Ro-

ration must have gone vastly swifter than the Annual Motion of a Comet; which yet is the only possible Mechanical Cause of any such Diurnal Motion of a Planet; nay so swift, that it would have exceeded the mutual Gravitation of its Parts, and the Earth would, by Consequence, have dissolved it self, and scattered those Parts into the Ether, without any Possibility of a Reunion into a Planet again. Nor do I believe, by what he has said already, that Dr. *Halley* himself will pretend to justify such prodigious Numbers, from any Phænomena of present Nature whatsoever. Ibid.

Coral. (10.) The same Reasoning is confirm'd from all the Records of Antiquity now extant; which never mention an Annual Period of more than 365¼ Days, or a menstrual Period more than 30 Days. Whereas any such vast Numbers, do, for certain, suppose that the Year and Month must have been of old more than so many Centuries of Days, as the Records ascribe to them single Days: And that Days and Nights, as distinct from each other, must have been at first hardly a few Minutes long; Which would be absolutely inconvenient for Mankind, and utterly without Example in the whole visible Universe.

Coral. (11.) But tho' we cannot, with sufficient Exactness, calculate *à priori*, or from direct Geometrical and Mechanical Reasoning, How long ago the Diurnal Motion, or Day and Night,

Night, began upon our Earth; yet may we, *à posteriori*, come very near to that Epocha: I mean by observing the Proportion of the Effects of this Retardation of the Diurnal Motion, or Lengthning of the Day, in the several Ages of the World; or by discovering how many Days have gone to a Month, or a Year, in all the several past Ages. For if the World has been a very great Number of Thousands of Years old in its present State, and without any great Change by a Deluge, we shall find that the Old Year must have been 1000 Days long, then 500, then 400, then 390, then 380, then 370, and at last only 365¼; and the Month in Proportion: Contrary to all the ancient Accounts, Records, or Traditions Sacred and Prophane: Which, on the other hand, ever assure us, that the oldest Year of all, and the almost only Year heard of till these last 3000 Years, was of fewer Days than the present, and indeed of no more than 360: And that the eldest Month of all, and the only one heard of till the same last 3000 Years, was of no more than 30 Days: As my Learned Friend Mr. *Allen* has fully proved in my *New Theory*. Near to which they are at this Time also.

Coroll. (12.) The Comparison therefore of the present Phænomena of Nature with all the ancient Records, implies, that the Year it self has been lengthened, since the Time that the ancient Year contained 360 Days: And that before that Time, the Number of Days had

been more and more, or that the Day had been ſhorter and ſhorter.

Corol. (13.) Since therefore no other Mechanical or Natural Cauſe could change the Length of the Year, but the Acceleration by a Comet; which would alſo naturally cauſe a general Deluge of Waters on the Earth; It is plain that theſe Phænomena of Nature, as compar'd with ancient Hiſtory, greatly confirm what I have long ſince ſuppos'd, and almoſt demonſtrated from other Evidence, in my *New Theory*, *viz.* That there was above 4000 Years ago a general Deluge of Water on the Earth; and that by ſuch a Cauſe as did lengthen the Year; and did alſo anſwer to all the Deſcription of that Flood in *Moſes*'s Hiſtory, and to the other Phænomena of Nature and of Antiquity. Which Account I ſhall therefore admit here as true; and make uſe of it in order to determine more exactly the Antiquity of our Diurnal Motion, or of the preſent State of our Earth; and in order to compare that Determination with the Sacred Chronology, and try its Veracity thereby.

Corol. (14.) Since therefore we now know, that the Difference of our Two Diurnal Motions is about the $\frac{1}{700000}$ Part of the whole Circle; that this Difference has ariſen according to a Geometrical Progreſſion; that the Difference of the preſent Day, from the ancient Day, at any determinate Period of Time backward, muſt

be proportionable to that Difference, and proceed in the ſame Geometrical Progreſſion therewith: Since alſo we know, that about 5000 Years ago, 354 of our Days was nearly equal to the ſame annual Space, which was then meaſured by no fewer than 360 Days; or that the Day was then about 20', or a 73d Part ſhorter than it is now: And ſince, laſtly, we alſo know, that the Day has not been conſiderably altered for theſe laſt 2400 Years; as the Compariſon of the oldeſt Eclipſes and Equinoxes with the preſent, does certainly demonſtrate: Since, I ſay, we have all theſe *Data*, as the Foundations of our Calculations, we may thence determine, in ſome meaſure, How long it has been ſince the Day had any Number of Minutes leſs than it has now; and ſo, very nearly, when that Diurnal Rotation, or the Day and Night firſt began: According to the following Series; where $\frac{1}{73}$ cannot be far off $\frac{1}{1}$, or the Year of 360 Days far off the Beginning of the Diurnal Motion.

$\frac{1}{1}$. $\frac{1}{7}$. $\frac{1}{70}$. $\frac{1}{700}$. $\frac{1}{7000}$. $\frac{1}{70000}$. $\frac{1}{700000}$.

By which it appears, that tho' we ſuppoſed the Earth to have had no Deluge by the Approach of a Comet, it could not ſtill be very much older than the 360 Days to a Year. Nor at all conſiderably older, without having had 370, 380, 390, 400, 500, and 1000 Days to a Year: for which we have not the leaſt Authority. That

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in Caſe we allow of a Deluge by the Approach of a Comet, it cannot be ſuppos'd older than Scripture affirms, without the ſame ill-grounded Hypotheſis, of the Year's containing ſuch a great Number of Days: But that in Caſe we allow of the Deluge by the Approach of a Comet, and determine, what all Antiquity demonſtrates, that the Ancient Year before the Flood contained 360 Days, and no more; the preſent State of our Earth will be the ſame Number of Years old, and no more, which the Sacred Scriptures do aſſure us it really was.

N. B. If Dr. *Halley*'s ſhorter Period of the Magnet's reſpective Revolution of about 700 Years, were the true one; it would imply, that the World were ſtill of a ſhorter Date, by ſome Hundreds of Years, as the Reader may eaſily obſerve, by beginning with 250000 inſtead of 700000. Nor can any Computation agree to the internal Motion before us, and to the ancient Year of 360 Days, but it muſt ſuppoſe that there has been a Deluge; that the Year has been chang'd at that Deluge; that I have truly aſſign'd the Cauſe of that Change at the Deluge, in my *New Theory*; and that the internal Conſtitution of the Earth there deſcribed, is alſo the true one: Every ſuch Computation will alſo certainly eſtabliſh the Bible Chronology; and demonſtrate, that the preſent State of the Earth has been of that very Antiquity,

and no other, which *Moſes* affirms concerning it in the Book of *Geneſis*; which Corollary highly deſerves the Conſideration of every one, who deſires to know the Truth, and to examine the Credit of the Sacred Scriptures by all proper Methods of Enquiry.

N. B. This Antiquity of the preſent State of the World, of about 6200 Years, (which, as I ſhall ſhew in my *Eſſay to reſtore the true Text of the Old Teſtament*, is the only original Scripture Chronology thereof) is greatly confirm'd from two moſt valuable Fragments of Heathen Antiquity, when connected together, as they are by the late Biſhop *Cumberland*, in his Valuable and Curious Diſcourſes not yet publiſhed, *Of the moſt Ancient Antiquities of the World*, corrected: I mean from the ancient Idolaters Genealogies in *Sanconiathon*, drawn down from the Beginning of the World till a little after the Days of *Miſor* and *Taaut*, or of *Miſraim* and *Thoth*, the two firſt Kings of *Egypt* after the Flood; and thence from the *Latercu-lus* of thoſe *Egyptian* Kings, beginning with *Menes* and *Athothes* I. or the ſame *Mizraim* and *Thoth*, preſerv'd by *Eratoſthenes* the great *Egyptian* Mathematician, and Keeper of the famous Library of *Alexandria*, and allowed by the Learned to be of the greateſt Authority of all others. Which entire Series, thus connected together, affords us an Heathen Chronology entirely independent on the Bible Chronology,

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and yet perfectly agreeable thereto; as I could here distinctly shew, were it my present Design; and would it not too much prevent the Reverend Mr. *Pain*, the Worthy Son-in-Law to Bishop *Cumberland*, who, with very great Labour, has retriev'd those last Remains of that very Learned Bishop, and intends in a little time to communicate them to the World. But to return.

Corol. (15.) What Dr. *Halley* has first asserted, and Sir *Isaac Newton* from him afterwards embrac'd, That since the oldest Observations of Astronomers, the Motion of the Moon, as compar'd with the Diurnal Motion of the Earth, has been a small matter accelerated, may, not improbably, be entirely owing to this small Inequality of the Days, of which we are now discoursing, and to nothing else. We now know, from certain Fact, that the Day must, in some degree, have been shorter formerly than it is now: We do not at all know in Fact, that the Moon has sensibly altered its Velocity: 'Tis therefore more reasonable to suppose, that this small Acceleration of the Moon is not real, but apparent only; and that the somewhat shorter Days by which its Periods ought to have been measur'd, but of which, till now, we were wholly ignorant, do give us the true Solution of that seeming Inequality; which is a necessary Conse-

Philos. Transact. N°. 218. *Princip. Edit.* 2. *p.* 481.

quence

quence therefrom. I wish Dr. *Halley* had prosecuted that Matter farther, as he promised to do, and had given us an Account, how much this seeming Acceleration has amounted to; because that Quantity would have been very valuable to me, in stating the Earth's Diurnal Motion for the several past Ages; and for want of which, among other Things, I have not been able to determine particular Numbers of Years to the Geometrical Progression above-mentioned.

Corol. (16.) There is however no Occasion to wait many Centuries of Years, in order to discover the Antiquity of the Earth, in its present State, from Natural Philosophy, or to introduce any uncertain Hypothesis about the gradual Saltness of the Ocean, and of certain Seas, as Dr. *Halley* proposes for a Calculation thereof: Since we have here at hand a much surer Method, and this not built on a bare Hypothesis, but on Fact, for discovering the same already; and that even from Dr. *Halley*'s own Concessions of the moveable Magnetick Poles of the Earth also. *Philos. Transact.* N°. 344. ut prius.

Corol. (17.) Since therefore it is evident from Natural Philosophy, especially as compar'd with all the oldest Records of Mankind, that the present State of this Earth on which we live, is of no other Antiquity than the Bible informs

informs us: And ſince the preſent Numbers of Men upon it could not have ariſen from a ſingle, or a few Pairs, as all the ancient Records agree they really did, according to the uſual Proportion of their Increaſe and Doubling, if their Lives had been of their preſent Brevity; 'tis plain, that the Sacred Writings have given us a true Account here alſo; and that the firſt Parents of Mankind, both before and after the Flood, lived much longer, and ſo doubled much quicker than we now do: Which Thing is fully confirm'd in all prophane Antiquity alſo.

Corol. (18.) Since therefore it is evident, from the ſtill remaining ſlower Revolution of the Earth's internal Loadſtone, that, in Dr. *Halley*'s Words above recited, "the Diurnal "Revolution has, moſt probably, ariſen from "the Impulſe whereby this Diurnal Motion "was impreſs'd on the Earth; being given to "the external Parts, and from thence, in Time, "communicated to the Internal; and ſince, as Dr. *Halley* well knows, no other Body in the viſible World is capable of giving ſuch an Impreſſion, but the Central Solid of a Comet; which I have conjectured in my *New Theory*, to have been the inſtrumental Origin of the Diurnal Motion: Let us ſee how the particular Velocity here aſſigned to this Earth at firſt, I mean between a 30th and 40th Part greater than it now has, will agree with the Velocity of Comets. Our Great Sir *Iſaac Newton* has

demonſtrated, that the proportionable Velocities of all Comets, at the Diſtances of any Planets from the Sun, are nearly one and the ſame; *i. e.* ſo much greater than the annual Velocity of every Planet, as the Diagonal is greater than the Side of a Square; or nearly as 10 is more than 7. It is alſo certain, that ſuch a Velocity is here to our Diurnal at the Equator, (along which alone that Diurnal Motion muſt have been at firſt impreſs'd) as about 77 to 1. If therefore that Comet's Central Solid had been as big as the upper Earth, and had hit againſt all its outward Parts directly; this Velocity would have been equally diſtributed between them both; and therefore would have been the one half of the Velocity of Comets; *i. e.* between 38 and 39 times the preſent Velocity. But then, becauſe this Motion was very oblique to the Earth, and ſo rather graz'd upon the outſide, than hit againſt the whole Maſs that was to be moved, otherwiſe a Diurnal Motion could not have ariſen thence; this Velocity would be ſtill much leſs conſiderable. And as Comets Central Solids alſo are frequently very much leſs than the Earth; ſo might they have impreſs'd a ſtill much leſs Quantity of Motion upon it. So that we can only hence certainly tell, that the Diurnal Velocity impreſs'd muſt have been much leſs than 77, moſt probably much leſs than 38 times the preſent Diurnal Velocity of our

Princip. L. I. Prop. XVI. Corol. 7. *and* L. III. Prop. XL. Corol. 3.

Equator; but cannot tell that it was at all greater.

Coral. (19.) Let us therefore leave this more uncertain Way, *à priori*, which cannot afford us any greater Accuracy; and proceed to another, *à posteriori*, from the Diurnal Revolutions of the reſt of the Planets; which in all Reaſon they every one at firſt obtain'd in the ſame way; whether that Way were Immechanical or Mechanical, which is of no Conſequence in this Corollary. And let us here ſee what Proportion any of them bear to the Diurnal Velocity of our Earth. For Fact is our ſureſt Guide in ſuch Matters: And 'tis the ſafeſt Way to ſuppoſe our Diurnal Velocity never to have much exceeded the Diurnal Velocity of one or other of the reſt of our Fellow-Planets. Now if we proceed thus, we ſhall ſoon find, that all Degrees of Angular Velocity much beyond double the preſent Diurnal Motion of our Earth, is without all Example in the whole Syſtem; and that the greateſt Part of the Inſtances are of Motions much ſlower than its own. To ſay nothing then of the Sun, which is near a Month in revolving round: The Moon herſelf revolves in no leſs than a Month's Time. Nay, *Mars* on one Side of us, and *Venus* on the other, which are the neareſt and beſt Inſtances, revolve little differently from our Earth at preſent; the former in 24 $\frac{2}{3}$ hours, the latter in 23. *Saturn* and *Mercury* are not yet certainly known to

revolve

revolve about their own Axes at all. *Jupiter* alone is known to revolve a good deal quicker than our Earth at preſent: Its Day being no longer than 9 Hours 56′. Which angular Motion is between twice and thrice as ſwift as the like angular Motion in *Mars*, the *Earth*, and *Venus*. So that, if we go the ſureſt Way, that of Fact; and chiefly by the neareſt and beſt Inſtances; the Earth's Original Angular Motion must not have been near thrice ſo ſwift as at preſent, and much the moſt probably but little ſwifter; *i. e.* its preſent State cannot, by the Phænomena and Series above, have been very much older; but with much the greateſt Probability, was not at all older than the Bible affirms: Which ſeveral coincident Methods of Examination, all of them coming to the ſame main Concluſion, highly deſerve every one's ſerious Conſideration.

Corol. (20.) Tho' we could not before with ſufficient Exactneſs, *à priori*, fix the Proportion, which the upper ſolid or conſiſtent Parts of our Earth, bear to the lower moveable Parts thereof; yet may we now, *à poſteriori*, nearly determine the ſame. For ſince the Proportion of the quickeſt Motion of the Earth to that of the ſloweſt, is the ſame with that of the whole Earth, which at laſt is moved to the upper Earth, which communicates that Motion to the reſt, according to the known Laws of the Communication of Motion in ſuch Bodies:

And

And ſince that Proportion is as the Time of revolving at laſt, when the Motion is all communicated, to the Time of revolving at firſt, when none was communicated; or, as we have ſeen, as about 365 to 355, or 36 to 35; (the Lengthening of the Year at the Deluge being not here concern'd;) it thence appears, that the entire Earth is to the upper ſolid Earth, as 36 to 35; and the Difference, or Quantity of the lower moveable Earth, conſiſting of the Central Magnet, and interpoſed Fluid, is to that upper ſolid Earth, as 1 to 35. Since therefore an outward Concave Sphere 2800 Miles thick, is to an inward Sphere of 1200 Miles Radius, nearly as 35 to 1; we may well ſtate thoſe Parts of the Earth accordingly. Tho' indeed what Proportion the internal Magnet bears to the upper Earth or interpoſed Fluid, we cannot exactly determine till we have better Obſervations. Only we may, if we pleaſe, reckon the Depth of the interpoſed Fluid not much different from the Semidiameter of the Central Loadſtone.

Corol. (21.) Upon better Obſervations, it will not, perhaps, be wholly impoſſible, *à poſteriori*, to determine hereafter, within ſome Latitude, the Nature and Denſity of the interpoſed Fluid, by which a given Motion, at firſt impreſs'd on the upper Earth, has, in a given Time, been communicated to the internal Loadſtone: Which Knowledge of that Fluid would

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be highly acceptable to the Inquiſitive; and make way for the farther Diſcovery of ſuch Uſes, as it may ſerve to in the Courſe of Providence, beſides that of the Communication of this Motion.

Corol. (22.) Perhaps therefore that Fluid may prove ſuch as is fit for Animals to live in; I mean either on the inner Surface of the upper Earth, or outward Surface of the Central Loadſtone, or elſe in the very Fluid it ſelf alſo; which laſt is the Caſe of the upper Surface of our Earth, and of the fluid Air above us. Nor does this Place, I confeſs, ſeem to me to be any other than the ἄδης of all Antiquity, Sacred and Prophane; of which it is not proper here to treat more largely. However, the Reader is deſired to conſult what I have elſewhere ſaid to this Purpoſe in my *Aſtronomical Principles of Religion*, Part V, and VII. and to underſtand thoſe Notions according to theſe Diſcoveries, and not otherwiſe.

Corol. (23.) Hence we may exactly compute the Inclination of the Dipping Needle for *London*, during the next 320 Years, till *A. D.* 2040, or 160 Years before and after the Magnetick Pole will come to the Meridian of *London*; which will not be till *A. D.* 1880, as in the following Table.

A. D.

A. D.	*A. D.*	*Inclin.*	
1720 and 2040	—— 75°.	10.	
1725 and 2035	—— 75.	17.	
1730 and 2030	—— 75.	23.	
1735 and 2025	—— 75.	30.	
1740 and 2020	—— 75.	36.	
1745 and 2015	—— 75.	42.	
1750 and 2010	—— 75.	48.	
1755 and 2005	—— 75.	55.	
1760 and 2000	—— 76.	00.	
1765 and 1995	—— 76.	05.	
1770 and 1990	—— 76.	09.	
1775 and 1985	—— 76.	13.	
1780 and 1980	—— 76.	17.	
1785 and 1975	—— 76.	21.	
1790 and 1970	—— 76.	24.	
1795 and 1965	—— 76.	27.	
1800 and 1960	—— 76.	30.	
1805 and 1955	—— 76.	33.	
1810 and 1950	—— 76.	36.	
1815 and 1945	—— 76.	38.	
1820 and 1940	—— 76.	40.	
1825 and 1935	—— 76.	42.	
1830 and 1930	—— 76.	44.	
1835 and 1925	—— 76.	45.	
1840 and 1920	—— 76.	47.	
1845 and 1915	—— 76.	48.	
1850 and 1910	—— 76.	49.	
1855 and 1905	—— 76.	50.	
1860 and 1900	—— 76.	51.	
1865 and 1895	—— 76.	52.	
1870 and 1890	—— 76.	53.	
1875 and 1885	—— 76.	54.	
1880 and 1880	—— 76.	55.	*N.B.*

N. B. That this Table being made from the Hypotheſis, That the Revolution of the Magnet is even, and will be no ſlower the next three Centuries than it was this laſt; which is not ſtrictly true; the real Times anſwering to each Dip are to be ſuppoſed ſomewhat later than thoſe here ſet down: But how much later cannot yet be exactly determined: And therefore I have not here made any Allowance for that Inequality.

N. B. Since it will hereafter appear, that the *Variation* of Magnetick Needles from the Azimuth of the Meridians of the internal Magnet, is deriv'd from the Difference of the Strength of the ſeveral Parts of the internal Magnet's Surface; which is no way to be known but by Experience; we cannot, with any Aſſurance, foretel that Variation as to our own Meridian's long before-hand. Unleſs where we have good Accounts, how that Variation from the internal Magnet's Meridian has been, in any Parallel, for the Ages foregoing. Which being not yet to be met with, even as to the Parallel of *London*, much leſs as to any other Parallel, I dare not venture at all to predict that *Variation*, as I have here done the *Inclination*: Only that it may probably ſtill return round, and be every where the ſame in any Year of the next Revolution of the internal Magnet, that it has been in the like Year of any former Revolution

thereof; or will it ſelf have a Revolution in ſomewhat above 1920 Years.

XXIV. Thoſe Two Magnetick Poles which Dr. *Halley* firſt introduc'd, and ſuppoſed fixed in our upper Earth; and that as neceſſary to ſolve the Irregularity of the Variation of the Horizontal Needle from the Meridians of the moveable Magnet within the Earth, of which in the Preface, have no juſt Foundation in Nature, but ought to be wholly rejected.

The Reaſon of this is very plain; that ſuch Irregularity of Variation belongs to our common *Terrella* or Spherical Loadſtone, as well as to the Earth's internal Loadſtone; as Dr. *Gilbert* has long ago obſerv'd; and as every body may ſoon ſatisfy himſelf upon Trial. Thus that *Terrella* which I have chiefly made uſe of, affords us but ſeldom a Direction ſtrictly along the Meridians; while the Needles vary ſometimes *Eaſtwards*, ſometimes *Weſtwards*: Inſomuch that between its *North* Tropick and Polar Circle, that Variation amounts, in one place, to above 30 Degrees; which is a Quantity rarely known upon the Earth it ſelf. Nor is the Reaſon thereof obſcure, *viz.* that Loadſtones have never been purified in the Fire, as Iron has; but are uſually ſtill compos'd of Parts of very different Degrees of Strength and Perfection; as all that cut them know very well: And that therefore where any

De Magnet. L. IV.

Parts

Parts are weaker than the reſt, the ſtronger neighbouring Parts prevail, and draw the Needles that way; as is the Caſe notoriouſly at the Place of greateſt Variation on the *Terrella* above-mentioned. Nor is Dr. *Gilbert*'s Notion of prominent or concave Parts, like Hills and Valleys, upon ſuch *Terrellæ*, as Occaſions of ſuch Variations, perhaps wholly unapplicable to the internal Loadſtone: Tho', I confeſs, I rather think the forementioned unequal Strength of its ſuperficial Parts to be generally the Cauſe of the Needle's Variation upon the Earth; as it evidently is ſo upon our *Terrellæ*.

N. B. This Variation, as to the Azimuth of Magnetick Needles, ſeems nothing at all to affect their Angle of Inclination or Dip; as I have exactly tried on the Place of greateſt Variation in the *Terrella* above-mentioned: Which Property is very wonderful, and highly remarkable; and what gives a vaſt Preference to Dipping Needles above Horizontal ones, in all ſuch Attempts for diſcovering both of Longitude and Latitude thereby. Dr. *Gilbert* indeed aſſerts the contrary. But ſince I perceive he did not diſtinguiſh between the *Strength* of the Magnet in the Elevation of a longer heavy Needle, and the *Angle it ſelf* of that Elevation, which in that Caſe is beſt ſeen in a ſhorter and a lighter one, he is therein evidently miſtaken. Accordingly I find, that in theſe Parts of the World, where the Variation

v. 10.

tion on the Azimuth is 25 or 26 Degrees *Westward* from the Meridians of the internal Magnet, yet is the Angle of Inclination below the Horizon the very ſame that our Diſtance from the *Northern* Pole of that internal Loadſtone requires; without any ſenſible Inequality at all on account of ſuch Variation. Which thing, as I ſaid, is *very wonderful*, and *highly remarkable*.

XXV. The Intervals between the Lines of equal Dip, taken in any equal Number of Degrees, as 10°. 20°. 30°. 40°, *&c.* are regular, and nearly, if not exactly, obſerve the Proportion of the Sines of ſuch Angles; whoſe Radius is a Quadrantal Arc, and begins where the Dip is perpendicular to the Horizon. The Lines themſelves alſo of ſuch equal Dip, approach to parallel Circles, about the Magnetick Poles of the Earth.

This Propoſition is proved both *a Priori*, and *a Poſteriori*: From the Experiment of the Situation of ſmall Needles, and their equal Dips, upon the Surface of Spherical Loadſtones; and from the Fact of the Diſtance and Poſition of ſuch Lines upon the Surface of the Earth, found by Obſervation there.

As to the former Proof, *a Priori*, I have myſelf exactly tried it upon Two *Terrellæ*, or Spherical

Spherical Loadſtones; I mean thoſe in the Poſſeſſion of the Right Honourable the Lord *Paiſly*: And have found that the Dip of the ſmall End of a Needle, below its Surface or Horizon, is at 22° ½ from its Equator, 41 ½ Degrees: at 45° from it, 60 Degrees: And at 67 ½ from it, 75 ½ Degrees: While at the Equator, this ſmall Needle lies along that Surface; and at each Pole ſtands perpendicular thereto. And in general, I find the Angles well enough anſwer to the following Table, made according to the Line of Sines, and beginning from the Poles.

Sines equally different.		Inclination. °	′
0.	0000.	90.	0
9.	1000.	84.	15
18.	2000.	78.	28
27.	3000.	72.	32
36.	4000.	66.	25
45.	5000.	60.	0
54.	6000.	53.	7
63.	7000.	45.	34
72.	8000.	36.	52
81.	9000.	25.	50
90.	10000.	0.	0

All which the Nature of the Line of Sines, and of no other Line, does exactly require.

The

The Lines of equal Dip are thereon alſo no other than the Parallels to the Equator; as all our Trials demonſtrate; and as every body uſed to Spherical Loadſtones will readily agree.

As to the latter Proof, *a Poſteriori*, it is to be taken, as to both Parts, from the Situation and Diſtance of theſe Lines of equal Dip, upon a Terreſtrial Globe or Map, made from the beſt Obſervations, whereon I have drawn them; and which, in both Caſes, do nearly and generally agree to this Propoſition.

N. B. The Quantity of this Angle of Inclination made by the Needle and the Horizon of a *Terrella* has been long ſought, but never found before. Dr. *Gilbert* thought, that at 45° the Needle pointed to the Pole, and that this Angle was there by Conſequence 67°. 30'. inſtead of 60°. and the reſt commonly followed him, without any ſufficient Experiments.

Lib. IV.

Corol. (1.) It appears from the Facts, that the proportional Diſtances of the Lines or Circles of equal Dip, taken along the Meridians of the internal Loadſtone; and from its Poles on each Side, are 360° of Dip in 272° of a great Circle on the Earth: I mean this as taken in groſs, and one with another; altho' ſometimes the Inequality will be on one ſide, and

and ſometimes on the other; as the Nature of the Line of Sines does require.

Corol. (2.) In order to the deſcribing theſe Lines or Circles of equal Dip upon a Globe, we muſt draw them through three obſerved Points where they can be had: or elſe through 2, or at leaſt 1 obſerved Point, and where we want them, through the Diviſions of the Meridians already mentioned, according to the Line of Sines: Reſpect being ſtill had to the Analogy of thoſe that are drawn through 3 obſerved Points: According to which Rule, I have drawn the Principal of them upon Mr. *Molyneux*'s Globe, for the eaſier Comprehenſion of the Curious.

Corol. (3.) Since it appears from Obſervation, that the Poles of the internal Magnet are conſiderably diſtant from the Poles of the Earth, theſe Parallels, or Lines of equal Dip, will very rarely be coincident with the Parallels of the Earth's Equator: Which yet is the only poſſible Caſe, where this Method will diſcover no more than the Latitude.

N. B. This Coincidence with our Parallels, ſeems now to be between *Europe* and *America*, near 30° *North* Latitude: To which alone, of all the Places now frequented in Navigation, this Imperfection of our preſent Method appears to belong. However, as the Uſe of very long Dipping Needles will reduce that Space to a ſmall Breadth, on each Side of ſuch coinci-

dent

dent Parallels; ſo will it be eaſy to avoid the Inconvenience ariſing therefrom. For ſince the Longitude may ſtill be found along other Parallels at a ſmall Diſtance both *North* and *South*, Pilots may eaſily ſail along one of thoſe Parallels, where the Longitude can be found, till they come to the Meridian of the Place they ſail to: And then they may run along that Meridian till they arrive there. Which will be the more eaſily done, becauſe the Parallel of that Place will, in this Caſe, be found by our Dipping Needle in the greateſt Perfection. Nor will the Length of this Courſe be conſiderably greater than the uſual one by the Rumb Line.

Corol. (4.) Where we have ſeveral good Obſervations of the Angles of Inclination or Dip, at conſiderable Diſtances from each other, we may nearly find the reſt now, by Analogy to the Line of Sines, without waiting for other Obſervations. Nor will Sea Charts made from ſuch *Data*, be wholly uſeleſs at Sea, even at preſent; becauſe the Obſervations to be made at ſome particular Places, eſpecially as join'd to the Uſe of the Line of Sines, will ſoon enable the Pilots to correct thoſe Lines of equal Dip upon their Charts, and to guide themſelves, in ſome meaſure, the reſt of their Voyage, by ſuch corrected Lines alſo. Though it muſt be confeſs'd, that ſuch Charts cannot but require many more, and much nicer Obſervations, than

we

we yet have, in order to their utmost Perfection.

Corol. (5.) The Perpendiculars to these Magnetick Parallels must be nearly the Meridians of this internal Magnet, and pass not far off its *Northern* Pole.

N. B. Since the Quantity of the Inclination of the Dipping Needle has varied here at *London*, [the only Place in the World where it has been long enough known to determine that Alteration,] not much above 3 Degrees in 144 Years: (As appears by Mr. *Norman*'s Original Quantity 71° 50′, compar'd with that now, 75° 10′;) and will alter much more slowly for a long time hereafter, as our Table in *Pag.* 76, shews: 'Tis certain, that Charts made with these Lines of equal Dip upon them, will serve, at least in these Parts of the World, many Years, without any Necessity of Alteration, or any considerable Inconvenience to Navigation.

XXVI. *Problem.* From Three Observations given, to find the Position of the Magnetick Parallels, or Lines of equal Dip, to the Parallels of the Earth, in every Country.

Let L be the Place of the First Observation: S of the Second: and C of the Third. The Position of the *Fig.* III.

Lines LS and LC being given with regard to LR a Parallel of the Earth: Take the Diſtances LM, LN, as is the Number of Geographical Miles correſponding to the Alteration of one Degree of Dip along the Line LC; to the Number of Miles correſponding to the Alteration of one Degree of Dip along the Line LS. Draw the Line MN, with its Parallels LB and SO. Theſe are Magnetical Parallels, or Lines of equal Dip; and determine the Angle BLR, which is their Inclination to the Earth's Parallels in that Country.

Thus, If with us L be *London*; where the Dip is 75° 10′. S be *Saltfleet*, at the Sea-ſide in *Lincolnſhire*, in or very near the Meridian of *London*, and at the Diſtance of about two Degrees, or 120 Geographical Miles; where the Dip is 77° 15′. and C be *Cheſter*, in an Angle of about 42 Degrees from the *North*, *Weſtward*; and at the Diſtance of about 150 ſuch Miles, where the Dip is 76° 22′. LM will be to LN, as 130, the Number of Miles for the Alteration of one Degree of Dip along the Line LC, to 58, the Number of Miles for the Alteration of one Degree of Dip along the Line LS; or nearly as 22 to 10. The Angle BLR, which is the Inclination of the Parallels, will be about 22°. And the *Firſt* and *Principal Magnetick Parallel*, or Line of equal Dip paſſing through *London*, will alſo paſs nearly through *Calais*, *Dover*, *Woodſtock* or *Blenheim*, *Hereford*, *Aberiſtwith* in *Wales*, and 20 Miles *South* of *Dublin* in *Ireland*. *Q. E. I.*

Corol-

Corollary. Since BR, is to RL, or the Change of the Dip along our Parallels, to the Change of the Dip along our Meridians [ſee either of the Maps] as 4 to 10. The Longitude may with us be diſcovered between the one half, and one third Part, as exactly as the Latitude, or in the Proportion of 4 to 10.

Corol. (2.) Since therefore 'tis eaſy in Fact to diſcover the Dip to 4″, as I have found by frequent Experience, 'twill be alike eaſy to diſcover our Latitude to 4 Miles, and our Longitude to 10 Miles.

N. B. The Poiſe made uſe of in theſe Obſervations is ſo neceſſary in our Needles of the ordinary Shape, that my Needles of one Foot, unpois'd, differed from the true Dip of thoſe of four Feet rightly pois'd here at *London*, no leſs than 1°. 25'. and thoſe of four Feet themſelves, when unpois'd, ſtill differ from themſelves, when poiſed, in the ſame Place, not leſs than 30 Degrees.

N. B. However, a ſmall Error in the placing of this Poiſe, is of almoſt no Conſequence as to the altering of the true Angle of Inclination. Thus if here in *England* we miſtake an entire Quarter of a Degree, in the true Place of the Poiſe, we ſhall err only Two Minutes in the Angle of Inclination. And the like is to be ſuppoſed in other Places.

A General OBSERVATION.

IT may possibly be here expected, that, after the Discovery of so many and so strange Phænomena of the Loadstone, I should offer some Philosophical or Mechanical Hypothesis for their Solution. Nor have I been wanting in my Thoughts and Endeavours that way. But not being able to satisfy my self at all in any such Hypothesis, I shall not propose any thing of that Nature to others. Sir *Isaac Newton* himself, in the 2d Edition of his most famous *Philosophiæ Naturalis Principia Mathematica*, after he had made the vastest and most amazing Discoveries about the Power of *Gravity*, and given us his Thoughts concerning *God*, in an admirable *Scholium*, is content to conclude his Work, without being able to give any Philosophical or Mathematical Account of that Power of Gravity; nay indeed very justly speaks so, as gives us the greatest Reason to suppose he believed it was not Mechanical, but deriv'd from the immediate Power of God himself, the Great Author of Nature. Nor did the very Learned Dr. *Bentley*, nor that Excellent Mathematician, the Editor, Mr. *Cotes*, at all mistake him, or the direct Tendency of his Discoveries; when the former in his *Boyle's Lectures*, and the latter in his *Preface* to that Edition, all along own and plead for the same Thing. Accordingly I am

P. 481—484.

driven, by the like Neceſſity, to Confeſs, that I can no way ſolve the Phænomena of Magnetiſm mechanically; nor can I ſo much as deviſe any ſuch Motion of a ſubtil Fluid belonging to the Loadſtone, as ſhall account for an Attractive Power in the Seſquiduplicate Proportion of the Diſtance reciprocally: Nor indeed, if I could deviſe any ſuch Motion of a Fluid, would that be a ſufficient Reaſon to determine, that ſuch a Fluid was the real Cauſe of thoſe Appearances, as Mr. *Cotes* has well obſerv'd in the like Caſe, in that Preface. Nay indeed, tho' I could prove the Being of ſuch a Fluid, and deviſe a proper Motion of that Fluid, and make it probable, that ſome hitherto unknown Property of that moving Fluid, made it certainly capable of ſolving theſe Phænomena mechanically; yet would this do no more than remove the immediate Power of the Supreme Being one Degree further. It ever appearing that the laſt Reſort, the final Reſult of all ſuch Mechanical Principles whatſoever, always do, always will, and always muſt be reſolved into the Immechanical Power and Efficiency of God himſelf, the Firſt and Continual Cauſe; the Firſt and Continual Mover; the Firſt and Continual, moſt Wiſe and Powerful Author, Diſpoſer, and Governor of the Univerſe: *In whoſe World we live*; and without whoſe conſtant Interpoſition and Providence, that *World of his in which we live*, would immediately diſſolve into a Chaos of Confuſion, if not be reduced into its firſt State

of Annihilation, or Non-Exiſtence. I ſhall therefore chuſe to end all in the honeſt Words of the firſt Inventor of the Dipping Needle, *Robert Norman*, relating to this Matter: "Now, ſays he, peradventure you will ask me, How this Stone hath this Power, and how it is ingendred? I am no more able to ſatisfy you therein, than if you ſhould ask me, How and by what Means the Celeſtial Spheres are moved? But that God, in his Omnipotent Providence, hath appointed it ſo to be: Which may ſerve for a general Anſwer to all ſuch curious Searchers of the ſecret Works of God in his Creatures. ——Now therefore, as divers have whetted their Wits, yea and dulled them, ſo have I mine: and yet in the End have been conſtrained to fly to the Corner Stone, I mean God; who hath given Power to this Stone, which was received at his mighty Hand in Creation."

New Attract. C. VIII.

PRO-

PROBLEM

To find the Longitude or Latitude by the Dipping Needle.

IF the Lines of equal Inclination or Dip below the Horizon, be drawn upon Maps and Charts, from good Obſervations, it will be very eaſy from the Longitude known, to find the Latitude; and from the Latitude known, to find the Longitude; and this both at Sea and Land.

Thus in that firſt Sketch of a Map for ſome Parts of *England* and *France*, here exhibited, where I either have my ſelf obſerved the Inclination with a Dipping Needle of one Foot unpois'd, the laſt Year 1719. or procur'd former Obſervations; *viz.* one at *Sarum*, made by Col. *Windham*; and another at *Roven* in *Normandy*, extant in Dr. *Power*:

Suppoſe we are travelling or ſailing along the Meridian of *London*, and we find the Angle of Dip or Inclination, with a Needle of one Foot unpois'd, to be 75°. 'Tis evident, that this Meridian, and the Line of this Dip, can meet no where but in the Latitude of 53°. 11′. which is therefore the *Latitude* ſought. Or

Or ſuppoſe we are travelling or ſailing along the Parallel of *London*, *i. e.* in 51°. 32′. *North* Latitude; and we find the Angle of Dip or Inclination to be 74°. This Parallel, and the Line of this Dip, can meet no where but in 1°. 46′. of *Eaſt* Longitude from *London*, which is therefore the *Longitude* ſought. But the ſmall Map hereto prefixed, makes this Method ſo very eaſy by bare Inſpection, that I need ſay no more about it.

N. B. The Caſe is the very ſame in the Second ſmall Map, containing the Obſervations I made this Year, 1720. with a Magnetick Needle of 47½ Inches rightly poiſed; and needs no farther Explication. Nor is the great Difference between the Dips in theſe Two Maps any Objection againſt this Method; becauſe when the ſeveral Needles come to have every one their proper Poiſe, and to be all adjuſted to one Standard, as they ought to be, that Difference will entirely ceaſe. And if we conſider the firſt Map, we ſhall find that the ſame Poſition of the Lines of equal Dip, which agrees to the Obſervations this Year, *viz.* that of 22 Degrees from the Parallels of the Equator, do alſo beſt agree to Two of the remoteſt and beſt Obſervations ſet down in the other Map, I mean thoſe at *Sarum*, and *Roven*; as will be obvious on a little Attention.

Corol. (1.) Hence we may find the Place where we are at Sea, by the Dipping Needle, even without the Knowledge of the Latitude.

For

For if either we know the Number of Leagues we have ſailed, or the Angle from the Meridian in which we have ſailed from any known Place, which may one or both be uſually done pretty nearly; the Interſection of a Circle of the given Diſtance, or of a ſtrait Line drawn in the given Angle, with the Line of the true Dip, will determine our Place, and at once give us both its Latitude and Longitude.

Corollary (1.) Hence we may correct all our Sea-Charts, and Geographical Maps of Countries, with their Ports, and that to great Exactneſs; thoſe of the Land eſpecially, where there can be no Difficulty in making the niceſt Obſervations.

Corol. (2.) Hence alſo, by the Help of a very few more good Obſervations, to be made at the *Lands-End*, *Scilly*, *Exeter*, *Dublin*, *Carliſle*, *Aberdeen*, *Uſhant*, *Limmerick*, *Yarmouth*, the *Texel*, and the like convenient Places, we may ſoon draw the Lines of equal Dip in our Coaſting Charts; which, uſed with a Dipping Needle of Four Foot long, will preſerve the Ships near *Great Britain* and *Ireland*; and particularly near *Scilly* Iſlands, from all Danger, for want of knowing their Longitude; or even their Latitude ſometimes alſo. Which Thing I would therefore humbly recommend to the Right Honourable, and others the Commiſſioners appointed by Act of Parliament for the Diſcovery of the Longitude, as the firſt Thing proper for their Conſideration.

Rules of Practice for the Management of the Dipping Needle, in order to the Diſcovery of the true Angle of Inclination.

(1.) RUB your Needle, the Edges on which it revolves, (which muſt be ſtrait Lines, exactly horizontal, and nicely poliſhed) and its Pivots playing thereon, with a clean Cloth or Handkerchief, that no Duſt or Dirt may cleave to them, or alter the true Poiſe; and that the Needle may move eaſily and freely.

(2.) By the means of the three Screws, adjuſt the Situation of the Pedeſtal, or Frame, to the Perpendicular; which a Spirit Level will exactly diſcover at Land; and which the Frame it ſelf at Sea cannot vary from, by its original Contrivance.

(3.) Remove the Poiſe to that Diviſion upon the Needle from the Center, which you expect the true Dip will have below the Horizon; as at *London* to 75° 10: becauſe the Dip is there 75° 10 below the Horizon; and ſo every where. If you find, upon Trial, that your Dip is a ſmall matter different from what you expected, remove your Poiſe a little, till it agree with the true Dip, as near as poſſible.

(4.) Set a ſmall Compaſs, or Horizontal Needle, on, or parallel to the Direction of your Inſtru-

Inſtrument; and remove your Inſtrument, till its principal Direction lies parallel to your ſmall Needle: For then, and then only is it in that Magnetick Meridian, and rightly diſpoſed to ſhew the true Angle of Dip or Inclination.

(5.) Put your Dipping Needle into its Place, the right Side or Edge upwards, and guide it within a few Degrees of that Situation, where you expect it will ſhew the Inclination: And, letting it freely oſcillate ſeveral times, note all along by the middle Point of Time, (from your Watch, or Pendulum, or Pulſe;) and alſo by the middle Point of the ſmalleſt Arc deſcrib'd, the middle Angle of each Oſcillation: Then ſet down that Angle in a Paper, as the true Angle of Inclination, by this firſt Method; as at *London* 75° 10.

(6.) Take off the Poiſe, and let the Needle find its own Equilibrium. Then remove the Needle about 6 Degrees on either Side; and count 4, 8, or 12 of thoſe Vibrations by your Watch or Pendulum; and ſet down the 4th, 8th, or 12th Part of that Number of Oſcillations, to be made uſe of preſently.

(7.) Then place the ſame Needle, without any Poiſe at all, in an Horizontal Situation; and count, in like manner, the Number of Seconds in half the Number of Vibrations here, as you did of Oſcillations there, (the half of theſe, if you pleaſe, with one, and the other half with the other Side upward:)

beginning ſomewhat above 30 Degrees on either Side the natural Direction of the Needle; and ſet down the one half the 4th or 6th Part of this Number alſo.

(8.) Then having firſt ſquared both the Numbers, work by the Rule of Three, thus: As the Square of the larger Number of Seconds, of the Vibrations; to the Square of the ſmaller Number of Seconds, of the Oſcillations: So is the Radius to be to a fourth Number: which will be the Coſine of the Dip. *E. G.* at *London* thus: 43.4 q = 1890.6 : 22 q = 484 :: 10000 : 2560 = Coſine 75°. 10′. Now if theſe two Ways of diſcovering the true Dip agree within about a Quarter, or however within Half a Degree, you may ſecurely take the former Dip, found directly, for the true one. But if they differ more than that, 'tis probable ſome Error has been committed in the Experiment, by reaſon of ſome Iron or Loadſtone too near the Needle; or becauſe the Frame was either not exactly Horizontal, or not truly in the Magnetick Meridian, as it ought to have been: In which Caſe the Experiment is to be repeated, for greater Satisfaction.

N. B. Since this Second Method cannot come near to the ſame Exactneſs with the Firſt, and is more difficult to be put in Practice, I rather *recommend* it to the curious Seaman, when he

he has any particular Doubt as to his Longitude or Latitude, or when he is near the Shoar, or when he has ſome reaſon to ſuſpect his Needle to be out of Order; than *require* it in the ordinary Courſe of his Practice. And indeed, if he will but make the other Obſervation at Noon, or at a ſet Time, every Day; there will be ſuch a natural Harmony and Analogy between theſe Angles of Inclination, as appearing upon his Journal, when carefully obſerv'd; and ſuch Diſcord and Diſagreement when careleſsly noted, that he will not be much liable to any conſiderable Error ariſing from this Head: Any particular Error of the Obſervation in one Day, being naturally corrected by the better Obſervations of the foregoing and following Days.

N. B. Since the Latitude, when we ſail within a Point or two of the *North* or *South*, is moſt exactly diſcoverable by this Method, as well as the Longitude ſomewhat leſs exactly, when we ſail along, or very near a Parallel, by even or proportional Alterations of the Dip every Day; in ſuch Caſes the obſerving Sailor will diſcover his Place originally, even without recourſe to his Chart, or to any other Method of Obſervation whatſoever.

N. B. Yet ſince the Courſe is very frequently upon other intermediate Points of the Compaſs; in which Caſe, the natural way of diſcovering

covering the Longitude is by the Intersection of the Lines of equal Dip, with the Parallels of Latitude; 'tis certain, that the oftener and the exacter we can take our Latitude at Sea, the more accurately shall we know our Longitude. Whence that newest and best Contrivance of the very Ingenious Mr. *Rowe*, whereby he can much more frequently, and somewhat more exactly than formerly take that Latitude, will be of great Use here; and will enable us to discover even our Longitude from this Method, to a greater Degree of Accuracy than we could otherwise do. To say nothing here of an Improvement of my own, to the like Purpose; of which more presently.

N. B. The best Place and best Way for using the Dipping Needle on Shipboard, I take to be these. That in or near the Lower Deck, as close to the main Mast as may be, or exactly where the Center of the Ship's Motion is, which is esteemed by the Ship-Builders to be, where the Surface of the Sea produc'd would cut the main Mast, (which Place must have no Iron at all within a Foot or two; and no great Quantity of Iron within a Yard or two of it:) a round and strong Hole be made, of about two Foot Diameter; that in this Hole be a strong Circular Horizontal Table hung, within a very strong Circle of Brass, which has two Axes, at right Angles one to another, in the way of Sea Compasses; that to the Bottom of this

this Table be firmly join'd, and, if need be, brac'd, a long and heavy *Pendulum*; as I may call it, (tho' ſomewhat improperly: for 'tis the Ship it ſelf, and not this, that principally oſcillates, in the way of a real *Pendulum*:) in order to keep the Circular Table Horizontal. Upon this Table place your Inſtrument, with its ſmall Needle to guide it to the Magnetick Meridian; and with its Spirit Level, if there be Occaſion, to guide it to the Horizontal Situation. For in this Method, as I have frequently tried my ſelf, and ſhewn it to many curious and exact Obſervers alſo, the ſhaking of the Ship is almoſt wholly avoided, and the Angle of Inclination is found near as exactly as it is at Land; where there is no Conquſſion at all.

N. B. Upon ſuch an Horizontal Table we may place Pendulum Clocks, Large Hour-glaſſes, or the like equal Movements, for the exacter Meaſure of Time, at leaſt for ſome Days, if not Weeks, in order to the Diſcovery of the Longitude by any other Methods which require it. Upon the ſame Table alſo may Inſtruments be plac'd for the exacter Diſcovery of the Latitude; at leaſt when the Sun ſhines at Noon: All which Methods have hitherto been too impracticable, for want of ſuch an Horizontal Table. And tho' this Table will not be free from all Degrees of Motion; yet will that Motion be very ſmall, where the Pendulum is 3 or 4 Foot long; and will ſtill be

be equally below the Horizon on one Side, and above it on the other: Which will hardly incommode the Accuracy of ſuch Movements and Obſervations at all.

N. B. I once thought to have ſhewn in this place, how the Inclination of the Dipping Needle might alſo have been found at Sea, without any Concuſſion from the Ship at all, in the Places of greateſt Danger, or within 80 or 90 Miles of the Shores, which the Seamen call the *Soundings:* I mean, by deſcending in a *Cloſe Chamber* or *Diving Bell*, to the Bottom of the Sea; and there making the Experiment: Which thing is by no means impracticable, as Dr. *Halley* well knows: [He having been One of Five at the Bottom, even in an *Open Diving Bell*, in 9 or 10 Fathom Water, for above an Hour and a half at a time, without any ſort of ill Conſequence, as himſelf informs us, *Philoſ. Tranſact.* N°. 349.] But becauſe I find, upon Trial, that there will ſeldom or never be Occaſion for ſo troubleſome and chargeable a Method, I omit what I had written on that Head.

N. B. Whether this, or any other Method, either for Longitude or Latitude, can be put in Practice in a very great Storm at Sea, I do not know: Only this I will ſay, that if, on the Expectation of ſuch a Storm, the Longitude and Latitude be known; and if, as ſoon as

ſuch a Storm is over, the ſame be alſo known, which ſuch a Storm can no ways hinder, there can be no great Inconvenience in not knowing either of them, during the Storm it ſelf; when the Seamen, to be ſure, are otherwiſe employ'd; and when it frequently happens, that ſuch their Knowledge would be of no Advantage to them: It being to ſmall purpoſe to know anew where the Ship is, or whither they are to guide her, at a time when ſhe either lies at Anchor immoveable, or elſe drives before the Wind, without ſubmitting at all to the Guidance of her Pilot.

Addenda & Corrigenda.

N. B. THAT in the Title Page, all the Copies of the *Sibylline* Oracles, as well as *Theophilus*'s Copy, have ὑλήνια, a Word not known in the *Greek* Language, inſtead of ληνοὶ.

PREFACE.

Page 20. *Line* 2. *for* particular, *read* but precarious.

Line 29. *Add:* However, I muſt not here omit that highly valuable Attempt which was made by Captain *John Wood*, a very Inquiſitive and Judicious Sailor, for the Diſcovery of thoſe Things by Theory and Practice together, which Mr. *Bond* was chiefly trying to do by Theory. For about this very Time, or *A. D.* 1676. this Captain *Wood* ſailed *North*, in order to diſcover the *North-Eaſt* Paſſage. Where one of the Reaſons that induced him to this Voyage, as he tells us himſelf, was this: 'That he 'having for ſome Years paſt framed an Hypo-'theſis of the Motion of the Two Magnetical 'Poles; (for, ſays he, Two ſuch there be:) 'And having by the Obſervations of all or 'moſt that writ of that Subject, with his 'own Obſervations, and coſtly Experiment, 'upon a great many Places of the Superficies 'of the Terreſtrial Globe, found out their

'Motion

'Motion very near: [The *Northern* Pole, he had juſt told us, 'he was certain was not the 'ſame with the Pole of the World.] Where-'by the Inclination of the Magnetick Needle 'under the Horizon in all Latitudes and all 'Longitudes; and Variation of the Compaſs 'might be found in any Place in this World, 'without the Aſſiſtance of any other Lumina-'ry: He wanted to come nearer the Pole, in 'order to better Satisfaction. Tho', as he 'tells us afterward, when he intended to have 'given a more full and nice Account of all the 'Experiments he had and ſhould have made; 'eſpecially thoſe of the Magnet, which he 'forbears to mention, becauſe he intended to 'publiſh them in a Treatiſe by themſelves; 'He, alas! with his Ship, loſt all his Papers, 'and with them all that he had in the World 'beſide'. See Sir *John Narborough*'s Voyages, *pag.* 150, 151. and *pag.* 195, 196. And this indeed ſeems to have been the laſt and beſt Attempt that has been made in this Kind to this very Day. And Pity, great Pity it was that it had no better Succeſs; and that it was not ſeconded by ſome other fit Perſon, or by the Publick afterward! Mr. *Bond* indeed once appeals to this Captain *John Wood*'s Obſervation in the Streights of *Magellan*, for the Confirmation of his Hypotheſis: But what that Obſervation was in particular, he does not inform us. I imagine he may mean that of his ſuppoſed Dip In Initio.

there, of 65°. 26′. which is not very remote from my own Determination of the ſame, deriv'd from other Obſervations.

Page 22. *L.* 11. *Add:* Dr. *Halley* did alſo himſelf make ſome uſe of a ſmall Dipping Needle, near the Iſlands of *Cape Verd*, and found that it there lay Horizontal, contrary to all other Analogy: as if there were ſome Rocks of Loadſtone there. But when he made the like Obſervation at the Iſland of St. *Helena*, he found the Dip there to be regular, and in a near Agreement with the beſt of the other Obſervations thereabouts, and to my own Theory.

Page 23. *Line* 3. *Add:* Only this they found, that near the Iſland of *Jerſey*; and in the *Eaſt Indies*, both very near the great *Cardomum* Iſland, in the *Streights* of *Malacca*; and on a Rock at *Pulo Condore*, their common Compaſs would turn ſeveral ways; and ſo muſt either have been over a Pole of the internal Loadſtone, or near ſome Magnetick Rocks: The latter of which Mr. *Pound* juſtly thinks to have been the Caſe in all thoſe Places. And indeed what Grounds of Suſpicion ſoever there may be as to certain Coaſts and Iſlands, where the Longitude cannot be wanted; and where, in caſe it were wanted, a ſmall Removal of the Ship would give it as before; there is not, that I know of, any certain Examples of Irregularity of the Dip in the open Seas; where alone we have the principal Occaſion for that Longitude; either from Iron Mines, which indeed make

little or no Impreſſion upon Magnetick Needles, even placed in the very Middle of them; or from Magnetick Rocks, or any other Cauſe whatſoever. Upon which Occaſion, Hear the moſt authentick Teſtimony of Mr. *Pound* himſelf, who has made Obſervations with a Dipping Needle in more remote Regions than any other Perſon whomſoever; and who has aſſured me by his Letters, 'That I was miſinformed, 'when I ſuppoſed he had affirm'd, concerning 'the Horizontal Needle, that it was ſo irregular in a certain Place of the *Open Seas*, that 'it would turn every way. And He declares, 'that it did ſo only in the forementioned Places 'between Iſlands, and on Rocks; (which might 'be great Loadſtones.) He adds, That he 'hath made Obſervations with the Dipping 'Needle in ſeveral Places at Land, [in the '*Eaſt Indies*,] which he eſteemed pretty good, 'and agreeable to one another; tho' they were 'all loſt at the Deſtruction of the Factory at '*Pulo Condore*', and his Memory does not now enable him in any Degree to recover them. The Obſervations themſelves alſo, which he and Mr. *Cunningham*, as well as Mr. *Hudſon*, Mr. *Noel*, and Mr. *Feuillee*, made in their ſeveral Voyages, already mentioned, give no certain Indications of any ſuch Irregularity at all.

Line 11, *&c. Dele:* and an Hypotheſis of his own, with reſpect to two large Magnets, which he ſuppoſed to be within the Earth.

Page

Page 25. *Line* 4, 5. *read*; than an Hypotheſis, ſuppos'd to be deducible from that Author's Obſervations, of two, *&c.*

At the End of the Preface add: Since this Preface was printed off, I have received Information from Mr. *Campbel*, a very inquiſitive Friend of mine, That the Mariner's Compaſs was, in ſome ſort, for certain, known in the *Southern* Parts of *France* above a Century ſooner than *John Goia* is generally ſuppos'd to have firſt applied it to Navigation in the *Mediterranean*. Of which Diſcovery I will give the Account in my Friends own Words, as follows: 'The following Lines are found in 'an old provincial Poet, commonly call'd, *Guyot de Provins*, who flouriſh'd before the End of 'the 12th Century. And by the Date of his 'Work, they appear to have been wrote in the 'Year 1180. And they contain ſo very clear 'and plain a Deſcription of the Mariner's 'Compaſs, as puts it paſt all doubt that 'twas 'known at that time.

Ycelle eſtoile ne ſe muet
Un art ſont, qui Montir ne puet
Par vertu de la Marinette
Une pierre laide & noirette
Ou li fer Volontiers ſe joint.

'I have put them down exactly as they ſtand 'in the Original, according to the Orthography and Spelling us'd at that Time. I ſhall 'now

'now give you their Tranſlation very near li-
'terally.

There is a Star that never moves; (meaning the
And there is an Art that never deceives (Polar one.
By vertue of the Compaſs,
And an ugly black Stone,
That always attracts Iron.

'Thoſe Lines are cited by Mr. *Fauchet*, a 'famous *French* Antiquary, who liv'd in the 'Reign of *Lewis* 13th, in his Book, entituled, '*Lés Antiquités de la France*; And from him 'by Mr. *Perrault*, in his Parallel of the An-'cients and Moderns with reſpect to Arts and 'Sciences, *T.* 3. And the Age of this Poet 'is as certainly known among his Countrymen, 'as we know that of our *Chaucer*.

BOOK.

Page 1. *Line ult. Add: N. B.* A good Needle of 4 Foot long ought, before it is touch'd, to be ſo nicely poiſed, that it will feel the 120th or 130th Part of a Grain in the horizontal Situation; and, as near as may be, in the perpendicular Situation alſo: Which laſt, as it is very much harder to do, ſo on its being well done depends the greateſt Accuracy of every Needle.

Page 3. *Line* 16. *read:* Of the pois'd Needle, about 75°. 10'.

Page 4. *Line* 9. *Add*: *N. B.* This Power of Magnetick Inclination in the horizontal Situation of my two long Needles, the one of 4582 ½. and the other of 4012 ½ Grains Weight, was ballanced, the former by about 1 ½, and the latter by 1 ⅛ Grains: Which is by a little above the 3000th Part of their entire Weight: I mean when hung at the *Southern* Extremity of each Needle.

Page 7. *Line* 14. *Add*: But if we make the Needles themſelves much broader and ſtronger in the Middle than towards the Ends; as has been ſometimes done formerly; we ſhall avoid the greateſt Part of this Power. Nay, perhaps it will not be impoſſible to avoid it ſo far, that we may not have Occaſion for ſuch a Poiſe at all. Any little Error that ſhall ſtill thence ariſe being eaſily allow'd for in the Charts belonging to this Method; which may be fitted exactly and ſolely to ſuch Needles, and not to thoſe that, by being truly pois'd, are more regular. I mean this only in caſe they be all made of one Length, Weight, and Standard. And perhaps this will be the beſt way for ordinary Practice at Sea. Experience will ſoon determine between theſe two Methods.

N. B. All ſuch Dipping Needles ought to be made ſo heavy, that by their Weight they may fix themſelves to certain Places of the Edges whereon they lie, to prevent their Removal any way. And a fourfoot Needle ought to be conſiderably above a Pound Weight for this purpoſe.

Page

Page 9. change the Places of the two Numbers 4584 and 4015.

Page 26. *Line* 3. *read* 39½. *Page* 27. *Line* 3. *read* 39½. *and* 626. *And Line* 10. *read* 626.

Page 33. *Line* 4. *read* 14⅛. *And Line* 7. *read* 7$\frac{5}{12}$.

Page 34. *Line* 8. *read* 75⅛. to the *Sinus Totus*: or as 9667 to 10000. *Line* 17, 18. *read* 14$\frac{6}{8}$ to the *Sinus Totus*: or as 2560 to 10000. which is nearly as 1 to 4. *Line* 23, *and* 24. *read* nearly as 500. and nearly as 1 to 2. *Line* 24. *dele* or as 11⅓ to 6.

Page 53. *Line* 15. *add*: By Mr. *Norman*'s Obſervation, Chap. *ult.* where he tells us, 'He 'had heard many ſay that had travelled far to 'the *Southwards*, that the horizontal Compaſs 'hath ſeemed to loſe his Force, and to wax 'weak and dull'. Which is neceſſarily ſo, whenever we are ſomewhat near a Pole, and no where elſe. By Mr. *Pound*'s and Mr. *Cunningham*'s Obſervations alſo; which, tho' made with a Needle not equally pois'd or hung, ſhew that their greateſt Angles of Inclination altered not very much in above 2400 Miles, near the ſame Road with the other; which could only happen in the Neighbourhood of ſuch a Circular Pole. *Line* 21. *add*: And, laſtly, by Captain *Taſman*'s Obſervations, made *A. D.* 1642. where not very far *Weſt* from *Van Diemens Land*, his Horizontal Needle would not ſtand ſtill upon any particular Point

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of the Compaſs: Which was a Sign it was then over the *Southern* Pole of the internal Loadſtone, as we have already remark'd, *pag.* 38. *priùs.* See Sir *John Narborough*'s Voyages, *pag.* 132.

Page 54. *Line* 15. *read*, and either two or four Points, by Mr. *Norman* himſelf, C. 9. See alſo *Gilb. de Magnet.* IV. 16.

Page 54. *Line* 22. *add*: *N. B.* This Propoſition, and thoſe that depend on it, as to the Exactneſs of the Numbers, relies on the Truth of Mr. *Hudſon*'s greateſt Dip; which both in the Text and Margin is ſaid to be 89½. tho' in Figures only: While the Analogy of the reſt of his own Numbers ſeems plainly to requireus to read rather 86½. Nor do my own Obſervations this Year, 1720. contained in the Second ſmall Map, well agree to that larger Number. So that till we have more exact Trials beyond the *North Cape*; or can find the very Place of the *Northern* Magnetick Pole more nicely ſome other way; the Reader is to ſuppoſe ſuch Numbers and Calculations to admit of a conſiderable Latitude. *Line* 25. *read* 69. or at 21. *Line* 26, 27. *read*, by *Ballaſore* about 90. *Line* 29. *read* 40.

Page 55. *Line* 2. *add*: Mr. *Pound*'s, and Mr. *Cunningham*'s, and Captain *Taſman*'s Obſervations.

Page 56. *Line* 13. *add*: What the State of the Magnetick Power of the Earth, or internal Loadſtone, beyond, or within the *Southern*

Circular Pole, is, does not yet fully appear by any Facts that I know of. Very few, if any, beſides Mr. *Pound* and Mr. *Cunningham* having ever made Obſervations either of the Variation or Inclination there. Only it ſeems to me ſomewhat probable, that the Dipping Needle will lie Horizontally at the Center, as it certainly ſtands perpendicularly at the Circumference of that Circle; or if it be otherwiſe, that the Dip will be perpendicular to the Horizon within that entire Circumference. But the Determination of this Matter muſt be left to future Trials.

Page 57. *Line ult. read*, almoſt.

Page 58. *Line* 12. *add*: *N. B.* This Propoſition is directly fitted to the Obſervations I made 1719. while thoſe I have made this Year 1720. require the Angle B L C, to be rather 22 Degrees; and by Conſequence the Angle B P C above 50 Degrees; and the Arc gone by the Pole in 144 Years hardly 25 Degrees; and its whole Period not leſs than 2000 Years. Farther Obſervations will determine between all ſuch Numbers.

Page 74. *Line* 23. *add*: *N. B.* All this Reaſoning conſiders the *Upper Earth*, here mentioned, as including that *Fluid*, near the Top, which in my *New Theory* I have, from other Evidence ſuppoſed to be there: Which being *denſer* than the ſuperior Parts, would ſo ſuddenly receive and communicate the Diurnal Rotation, that it may here be well included under

that entire *Upper Earth* of which I am here treating, as distinct from the much lower, and vastly rarer Fluid, and from the Central Loadstone, therewith encompassed. Nor indeed, will any such Quantity as 50 or 100 Miles of such a dense Fluid; encompassed perhaps with 100 or 200 Miles of an *Upper*, and about 2500 or 2600 Miles of a *Lower* solid Earth, deserve much other Consideration in this Place, than if the entire *Upper Earth* were supposed to be throughout one continued solid Earth, without the Interposition of such a Fluid.

Page 80. *Line* 9. *add*: *N. B.* The Difference of this *Strength* of the Magnetick Power, from its *Direction*, is most visible in my Second Map hereto prefix'd: Where I have all along set down the Seconds wherein my Needle perform'd a single horizontal Vibration, at about 120 Degrees from the Magnetick Meridian, in most Places: Whose Squares, when Allowance has been made for the different Obliquity of the several Directions as to our Horizon, will give us the different *Strength* of that Magnetick Power at those several Places: As does the Angle of Dip give us the different *Direction* of the same Power there. Now at the first Sight, the former there appears to be irregular, and the latter regular; as is the Case also of our *Terrellæ*.

Page 82. *Line* 27. *read* 280.

Page 85. *Line* 6. *add*: *N. B.* Tho' the *Terrellæ* seem to give us these Angles exactly enough,

enough, on their Surfaces, according to the Line of Sines; yet may both they, and the *Earth's Loadſtone* alſo, at great Diſtances from ſuch Surfaces, admit of ſome Variation of that Proportion; as Dr. *Gilbert* has particularly obſerv'd in the former Caſe: and as many of the Obſervations on the Earth ſeem to require in the latter. Experience alone can determine this Matter. Nor is it of any great Conſequence, as to the Diſcovery of the Longitude or Latitude, How it is determined. For whatever this Proportion proves to be, when it is once known, it will be almoſt equally advantageous to ſuch Experiments.

Pag. 100. *Line* 4. *add*: *N. B.* The true Reaſon why the round Table guided by a Pendulum, will not oſcillate with the Ship; and why the Magnetick Needle will not vibrate either with the Ship or Pendulum, is evidently this; that the ſeveral Times of each of theſe Oſcillations, or Vibrations, are ſo entirely different, that their beginning Motions do mutually hinder their Influences upon each other, as do Diſcords in Muſick. Thus a Ship rolling in 7″, when compar'd with a Pendulum oſcillating in 2″, or a Magnetick Needle oſcillating in 17″ or 22″, or vibrating in 44″, are ſo diſſonant and diſagreeable, that they cannot conſiderably influence each others Motions; which Diſagreement, or Diſſonancy of the Motions, muſt therefore ever be taken exact Care of, in all Caſes of this Nature. And as

the Degree of this Avoidance of the Ship's Motion by the Pendulum, and of the Exactneſs of the Needle's Vibrations notwithſtanding that ſmall remaining Motion, I Appeal to Mr. *Molyneux*, Dr. *Deſaguliers*, and Mr. *Machin*, all Worthy Members of the Royal Society, and Eye-witneſſes; who I doubt not will do me Juſtice in this Matter.

N. B. The Reader is to remark, that it having hitherto been eaſy to poiſe Needles in their Horizontal, and very hard to poiſe them in their Vertical Situation, it has been much eaſier to find the Equator, than either of the Poles of the Internal Magnet by the Dipping-Needle: And that the other Method, by the Horizontal Needle, when it will turn every way equally over ſuch a Pole, is almoſt the only one that will ſtill find it exactly. However, the Obſervation is evident in Fact, that while ſeveral Dipping-Needles have hitherto conſiderably differ'd near the Magnetick Poles, they have agreed much better about their Equator: as they muſt needs do in their preſent Conſtruction.

POSTSCRIPT.

AFter all my other Trials with Braſs or Steel Edges, or Cylindrical Needles, for the Pivots of my Dipping-Needle to play upon,

upon, I have at laſt tried almoſt the ſame with Mr. *Norman*'s own firſt propoſed Method; *viz.* that of the plain Surface of Coach-Glaſs; which I find to be, at leaſt, twice as exact, and as ſure as any of the reſt; which Method therefore I intend ever to put in Practice for the future; and which I find will diſcover the Latitude, even in theſe Parts of the World, to *two* Minutes or Miles, and the Longitude to *five*.

I have alſo very lately been ſhewn by Mr. *Hutchinſon*, a very Curious and Inquiſitive Perſon, a Copy of a MS. Map of the World, made about 80 Years ago, taken by himſelf from an Original, wherein the Variation is reduc'd to a Theory, much like that which Dr. *Halley* has ſince propoſed; and in general exactly agreeing to his Obſervations, as he freely confeſſes; but with this Advantage, that therein the *Northern* Pole of the internal Loadſtone is much better ſtated than it is by Dr. *Halley*: And indeed is here plac'd almoſt in the very ſame Parallel and Meridian, wherein, by my other Obſervations, it muſt have been at that Time: Its Place then being, according to this unknown, very curious and ſagacious Author, about the Meridian of *Moſcow*, and the Latitude of 78 $\frac{1}{4}$ Degrees. Which ancient and authentick Determination of its Place, I deſire the Reader particularly to obſerve, in Confirmation of my foregoing Theory.

LONDON,
Jan. 28. 17$\frac{10}{11}$.

Will. Whiſton.

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